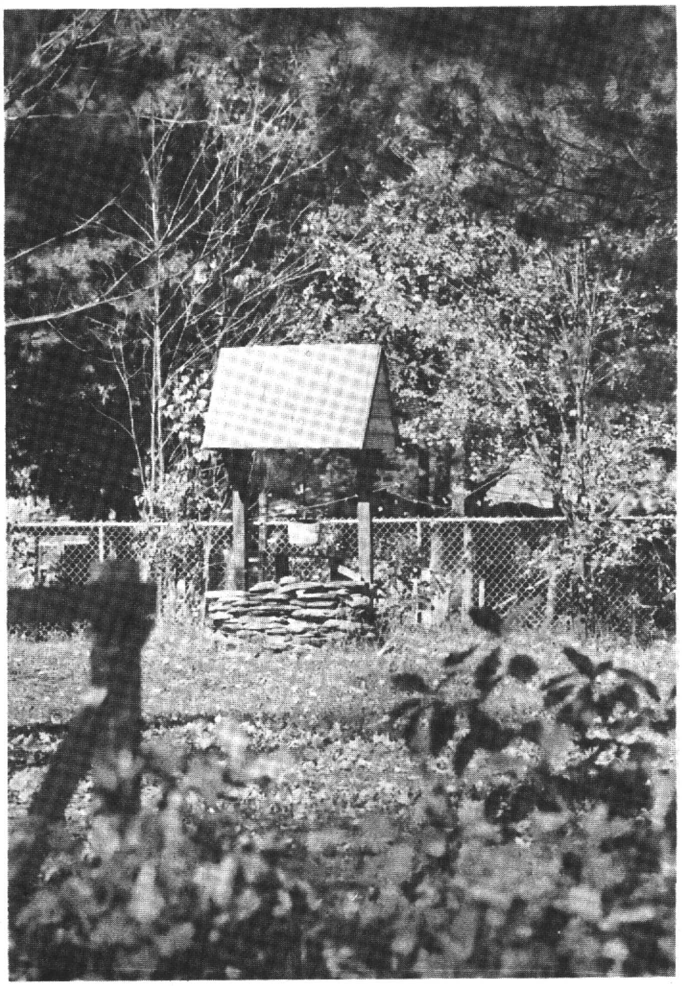
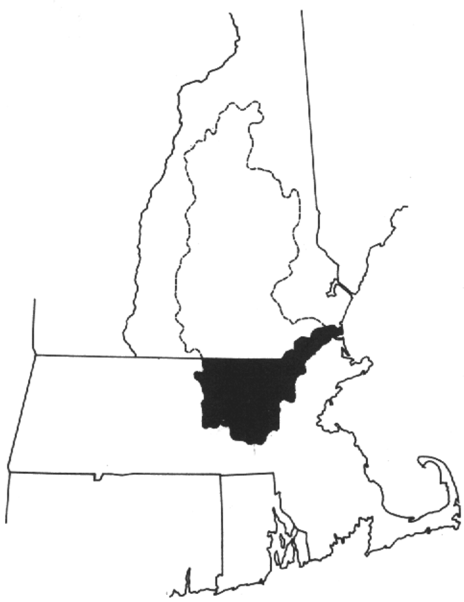
MERRIMACK WASTEWATER MANAGEMENT

key to a clean river



APPENDIX IV-D

HYGIENIC-PUBLIC HEALTH



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

NOVEMBER 1974

MERRIMACK WASTEWATER MANAGEMENT
INDEX TO REPORT VOLUMES

MERRIMACK WASTEWATER MANAGEMENT

(KEY TO A CLEAN RIVER)

APPENDIX IV-D

PUBLIC HEALTH SIGNIFICANCE

OF EXISTING WATER QUALITY AND WASTEWATER DISPOSAL

PRACTICE AND RECOMMENDED WASTEWATER MANAGEMENT

November 1974

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ADDENDUM

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A. INTRODUCTION

It has become increasingly evident that the increase in population, the demand for land and the movement of people from the cities to the surrounding areas has resulted in extensive pollution of both surface and groundwater resources. Public and private water supplies have also been polluted by improper environmental management of liquid and solid wastes.

The sources of pollution involve overflowing individual sewage disposal systems, either directly to streams or to groundwater aquifers, overloaded and malfunctioning municipal and industrial waste treatment plants, municipal and private solid waste dumps, sludges from municipal and industrial treatment plants and from individual septic tanks, runoff from paved areas and agricultural sites, and improper land use.

Water pollution occurs in part due to mismanagement through a lack of foresight and expertise at the design level, lack of enforcement of existing laws, disregard for the environment, lack of available technology, lack of money due to priorities, lack of cooperation between public agencies, and employment of unqualified personnel.

The Merrimack River Basin has a number of small feeder streams and five main river systems the Nashua, the Concord, the Assabet, the Sudbury, and the Merrimack. The Concord and Merrimack are water supply sources even though they are heavily polluted with sanitary and industrial wastes. Many of the small streams are sources of surface water supplies as well as indirect sources of groundwater supplies.

Therefore, there exists in the Merrimack Basin possible health hazards, either through consumption of contaminated waters due to failing or inadequate treatment plants, or by direct contact with these waters in water contact sports.

This report deals with the existing conditions in the Merrimack River Basin, the public health problems associated with these conditions and the impact of implementing each of the five wastewater management alternatives in terms of public health.

The addendum includes a literature review of the public health hazards associated with wastewater and the effectiveness of reducing these hazards by the various wastewater treatment processes. Those who are unfamiliar with this field will find it helpful to review addenda I and II before reading the main report.

B. PURPOSE AND SCOPE OF STUDY

The purpose of this study is to determine where public health hazards exist in the Merrimack Basin, their causes, what can be done to reduce these hazards, and how the alternative plans will accomplish this reduction.

Because of this concern and after interviews with Federal, State and local officials, a contract was signed with the United States Environmental Protection Agency in July 1973. This contract included an analysis of 164 water quality stations located throughout this basin, extending west to Ashburnham, north to the New Hampshire border, east to Salisbury and south to Worcester, Shrewsbury, and Westboro. The completion of this nine-month study showed the conditions of the environment upstream from the four main rivers as well as general conditions in the four main rivers. The streams sampled were grouped as follows: baseline or natural streams, recreational, water supply, and other feeder streams not used for either recreation or as a water supply.

Analysis data on 12 small feeder streams from uninhabited areas were collected to obtain a baseline data of natural water quality. All these streams are located in the western and northwestern area of the basin. The population density and activities of the area were the criteria for defining these streams and excluding the water quality sampling data from streams in other areas.

This study also included water quality sampling surrounding both sanitary landfills, and at the effluents of existing sewage treatment plants to determine their reliability.

Throughout the Merrimack Basin, the studies reveal that present policies and practices of wastewater management must change if recreational water contact sports are to exist and water supplies for the people of the Merrimack Basin are to remain pure. Unless the watersheds of domestic water supplies are protected from poorly planned and mismanaged urban development, it is our opinion that a major enteric disease outbreak may occur in one or more districts by 1990. An enteric disease outbreak involving 11,000 people recently occurred in California. (9) In addition, two enteric disease outbreaks have occurred in Vermont, and most recently another outbreak occurred in Meredith, New Hampshire. This documentation indicates the necessity of improved environmental wastewater management control. We must also consider the potential health hazard associated with the rapid movement of people from one country to another, and possible outbreaks of other diseases not generally occurring in the United States or New England.

C. FEDERAL AND STATE POLLUTION CONTROL LAWS

An effective wastewater management plan cannot be implemented unless current pollution control laws are strictly enforced.

1. Federal laws

In 1972, Congress passed Public Law 92-500; amendments to the Federal Water Pollution Control Act. The objective of the Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters.

Title IV, section 402 of the Act establishes the National Polutant Discharge Elimination System Permit Program. The program requires anyone responsible for a discharge to any water of the United States to obtain a permit from the Environmental Protection Agency. All industrial discharges must install best practicable control technology by 1977 and best available control technology economically achievable by 1983. Municipal treatment plants must have secondary treatment by 1977 and best practicable control technology by 1983. This will insure that all waters will meet water quality standards by 1977 and fishable, swimmable status by 1983. The 1985 goal is to achieve zero discharge of pollutants.

Title I of the Act declares goals and policies, provides for research training and demonstration grants, and calls for the Administration of EPA to encourage interstate cooperation and uniform State laws. In addition, it provides grants to state and interstate agencies to strengthen their existing programs or to create new ones.

Title II of the Act provides for Federal grants for the construction of publicly owned treatment plants, areawide waste treatment management, and basin planning. It further provides that alternative waste management techniques be considered and evaluated.

2. Massachusetts State Laws

One of Massachusetts basic public health laws dealing with disposal of sewage is Chapter III, Sections 5 and 17 of the General Laws. These sections have been in effect for nearly 100 years.

Section 5 had its beginning in 1869 when the first State Board of Health was established. About 1901, laws for the further control of disease, especially typhoid fever, were passed by the Massachusetts Legislature. Also, about this time, the Board was granted power to examine all sewers in towns and cities and evaluate the effects of sewage disposal.

Section 17 was enacted in 1886. This section gave the State Board of Health the power to protect inland waters. In 1888, the State Board was given the authority to recommend the proper disposal of sewage and prevention of pollution and removal of pollutants.

In 1914, the Legislature established the Massachusetts Department of Public Health, headed by a Commissioner.

About 1917, Massachusetts passed an act under Chapter 190 whereby the Department of Public Health was given responsibility for water supplies and inspecting sewage outlets and to report their findings to the General Court.

In 1937, an act was passed requiring State approval of all systems for water supply, sewage disposal and stormwater drainage. The act required plans to be submitted to the Department of Public Health for its advice and approval and stated that no system could be installed without State approval.

In 1956, Chapter 139 was enacted which eliminated the public hearing requirement prior to approval of sewage disposal facilities.

In 1962, the Massachusetts Department of Public Health, acting under Chapter III, Section 5 and Section 127-A, adopted what is known as the State Sanitary Code, Article XI, "Minimum Requirements for the Disposal of Sanitary Sewage in Unsewered Areas."

Article XI is an attempt to bring about a uniform basic engineering approach to the individual domestic waste disposal problem by setting minimum standards and guidelines to be followed by all cities and towns.

In substance, Article XI includes the following:

(1) Definitions. A total of 45 sanitary engineering terms involved in an individual land disposal system are defined.

(2) Permits. Permits are required for the construction, installation and use of individual sewage disposal facilities. A sewer permit is required before a building permit can be issued. In towns that do not require a building permit this provision does not apply.

(3) Sewage Flow Estimates. Guidelines for estimated water use, in gallons per person per day, are listed for individual homes, nursing homes, office buildings, schools, motels, parks, country clubs, churches, recreational camps, drive-in theaters, hospitals, factories, restaurants, laundromats, dry goods stores and an array of other establishments.

(4) Location. Minimum distance requirements from streams, wells, property lines, foundations, water lines, edge of slopes, etc., to reduce or prevent pollution are given.

(5) Building Sewers. A minimum pipe size of 4 inches is established. Materials, grades, alignment, etc., are covered, based on sanitary engineering principles.

(6) Septic Tanks. Size limitations are set; minimum 750 gallons, maximum 20,000 gallons. Any tank greater than 20,000 gallons must have special approval from the Department of Public Health. Construction and design details are also specified.

7) Dosing Tanks. To insure equal distribution of the sewage effluent to the final land disposal area, specifications for the hydraulic design of the system are set down.

(8) Disposal Fields. Specifications were provided for minimum distances to the groundwater, kind of stone to be used, size of the area, filled area, backfilling, disposal field construction, and location.

(9) Percolation Tests. Methods for conducting percolation tests are outlined in detail.

Currently, Chapter III, Section 17 of the General Laws requires that the Massachusetts Department of Public Health approve all plans for individual sewage disposal systems for motels, overnight camps, trailer parks, recreational camps, nursing homes, rest homes, police stations, schools, publicly owned buildings and all systems which treat over 2,000 gallons per day of sewage.

This chapter also grants authority to the Department of Public Health to require a city, town or water company to make improvements to any existing treatment work, if, in its judgement such work is necessary for the protection of the public health. A public meeting concerning the improvements is required.

In 1973, the Massachusetts Clean Waters Act, Section 26 of Chapter 21 of the Massachusetts General Laws, was amended. These amendments are similar to the 1972 amendments of the Federal Water Pollution Control Act and outline cooperation with Federal, interstate and other state agencies in securing the benefits of Public Law 92-500. A permit program for all discharges into waters of the Commonwealth is also authorized by these amendments.

Massachusetts stream classifications and water quality standards for the Merrimack River Basin can be found in the addendum.

D. BASIS FOR PUBLIC HEALTH EVALUATION OF WASTEWATER MANAGEMENT

The public health evaluation of wastewater management must consider a number of items. Among the areas to be considered are: public water supply, recreation, vector control, solid waste management, radiological health, and air pollution.

Provision of adequate quantities of safe water for drinking and other human uses is important to the public health both because contaminated water can produce disease, and because the ready availability of safe water can stimulate better personal hygiene, thereby resulting in improved health. The protection and safety of a public water supply system depends on the sanitary environment, quality and quantity of water sources, the effectiveness and reliability of treatment processes, the integrity and capacity of storage and distribution systems, quality control surveillance, and the qualifications and effectiveness of the operating personnel.

Public health evaluation of recreation areas must consider the drainage, soil permeability, groundwater location, and possible effects of swamps, streams, and lakes on health and safety. Proper collection, treatment and disposal of sewage wastes to prevent pollution hazards that may cause disease or illness must be considered. The water quality must be determined to establish the type of recreation allowed. In addition, the effect of insect and rodent control must be considered to protect the health of people using the recreation facility.

The prevention and control of vector problems requires that special emphasis be placed upon the prevention of physical conditions which may result in increased vector populations and upon the establishment of physical conditions which will minimize or eliminate existing vector problems.

Solid waste management and its potential effects should be considered in water resources development projects, particularly where water quality and recreation are important. Food supply for insects and animals which are disease vectors, surface and groundwater pollution, accident and fire hazards, and esthetic insult often result from improper storage of solid waste.

With regard to radiological health aspects of water resources, the problem areas; sources, mechanisms of exposure and surveillance should be considered. The sources of radioactive water contamination are numerous and include hospitals, industrial laboratories, nuclear reactors, fuel fabrication and reprocessing plants. Exposure is possible through contamination of water supply or recreation areas; and through food products. A surveillance and control program proposed for facilities releasing radioactive wastes to surrounding waters depends upon the facility type and the levels of activity discharged.

The popular concept that air pollution and its effects were restricted to the heavy industrialized urban areas of the country has been exploded, and today it is recognized that air pollution is of concern in suburban and rural areas as well. Analyses of numerous epidemiological studies indicate an association between high levels of air pollution, as measured by particular matter and sulfur dioxide, and the occurrence of health effects. In view of significant effects which air pollution control can have on water pollution and other environmental factors and the significant effects which water resources development can have on industrial development and other factors which may increase air pollution problems, it is imperative that air pollution aspects be considered in water resources planning.

Diseases of importance in a wastewater management program are listed below. The information was compiled from the "Annual Supplement of Morbidity and Mortality" published by the U.S. Public Health Service National Center for Disease Control. (34)

TABLE 1

TOTAL CASES IN MASSACHUSETTS

	1965	1966	1967	1968	1969	1970	1971	1972	1973
Amebiasis	5	5	0	0	4	3	1	3	4
Infectious Hepatitis	721*	557	716	974	2157	2033	1431	1593	1299
Salmonellosis	908	1033	979	1001	1423	1005	1035	814	802
Shigellosis	48	587	373	338	325	508	367	381	453
Typhoid Fever	3	9	7	8	10	11	13	13	19

* Total of infectious and serum hepatitis

TABLE 2

TOTAL CASES IN THE UNITED STATES

	1965	1966	1967	1968	1969	1970	1971	1972	1973
Amebiasis	2768	2921	3157	3005	2915	2888	2752	2199	2235
Infectious Hepatitis	33856*	32859	38909	45893	48416	56797	59606	54074	50749
Salmonellosis	17161	16841	18120	16514	18419	22096	21928	22151	23818
Shigellosis	11027	11888	13474	12180	11946	13845	16143	20207	22642
Typhoid Fever	454	378	396	395	364	346	407	398	680

* Total of infectious and serum hepatitis

E. EVALUATION OF MUNICIPAL WASTE TREATMENT SYSTEMS

1. Sewage Treatment Plants

The planning, design and construction of a sewage treatment facility does not necessarily mean that the pollution problems existing in the river or stream will be eliminated. The facility must operate at maximum efficiency at all times, to insure maximum removal of pollutants and minimal levels of polluting material from entering the streams. The design of the plant should be such that the effluent will not violate established water quality standards and that at least secondary treatment is being installed.

To determine the effluent quality of various sewage treatment plants in the Merrimack Basin samples were collected at eleven sewage treatment plant outfalls. Two treatment plants discharging to land disposal sites were also sampled. The data is shown on Tables 4 and 5.

All the facilities consist of secondary treatment plants with the exception of the Newburyport plant, which consists of primary treatment followed by effluent chlorination. The Marlboro East Sewage Treatment Plant consisting of a trickling filter was replaced with a new 2 stage activated sludge plant; the March through May analyses showed marked improvements in water quality and corresponds to the operation of the new facilities. Clinton Sewage Treatment Plant does not have effluent chlorination and as a result high bacterial counts can be found in the effluent. Shrewsbury and Westborough have excessive infiltration in their collection systems and hence hydraulic overloading reduces the efficiency at the treatment plants. The December analysis of the Newburyport Sewage Treatment Plant effluent showed an effluent containing high metal concentrations being discharged into the Merrimack River Estuary.

EPA has promulgated effluent standards for municipal treatment plants, which include effluent limitations for fecal coliform of 200 colonies per 100 ml on a monthly average and 400 colonies per 100 ml on a weekly average. With the exception of Newburyport and the new Marlboro East plant, all the treatment plants analyzed are not meeting this standard. Inadequate or nonexistent chlorination facilities or poorly operated facilities are the primary causes. Upgrading of these existing plants and better plant designs for new facilities should be forthcoming as a result of the municipal permit program and the established effluent standards. The Marlboro east plant is a example of what can be expected from a well designed and operated treatment plant. However, it is not without its problems, such as power failures. Additional facilities, beyond secondary treatment, may be necessary in water quality limited areas to meet stream standards.

The two plants listed in Table 5 treat their wastewater and then discharge to a leaching lagoon. These disposal sites consist primarily of forested land. Mt. Pleasant Country Club treatment facility does

Table 4
Merrimack River Basin
Water Quality Analysis of
Wastewater Treatment Plants

Station	Treatment Plant	Fecal Coliform / Total Coliform: Aug	Sept	Nov	Mar	Apr	May	Chlorides: Aug	Sept	Nov	Mar	Apr	May
1	Cushing Academy STP Ashburnham	2,000 / 2,000	39,000 / 420,000	5,500 / 5,500	310 / 15,400	45,000 / 420,000	2,000,000 / 3,100,000	27	16	1	38	33	35
12A	Clinton MDC STP					430,000 / 460,000	160,000 / 570,000					72	
13C	Concord STP			370		26,000 / 95,000	10 / 10						
15	*Marlboro STP East	3,100,000 / 3,100,000	3,400 / 23,000		0 / 0	0 / 10	200 / 780	210	50		10	85	
35	Marlboro STP West	0 / 0	0 / 2	3,800 / 83,000				40	60	29			
32A	Dracut STP		2,300 / 38,000	2,400 / 34,000	700 / 9,900	1,800 / 8,800	760 / 8,200			15	11	18	
46	**Newburyport STP	0 / 0	0 / 10	10 / 800	0 / 0	0 / 2	0 / 0	84	130	360	115	96	
62	Shrewsbury STP		170	10,000	990	15,000	150,000		30	50	43	50	
63	Westboro STP	53 / 12,000	0 / 30	10,000 / 100,000	4,700	200,000 / 510,000	380 / 43,000	75	70	65	64	70	
40a	Concord Reformatory STP			1,600 / 9,000		890 / 121,000				30		37	
58	Shirley STP	600 / 600		1,300 / 22,000	0 / 1,900	28,000 / 400,000		31		21	22	37	

Table 4 (Cont.)

Treatment Plant	Nitrates						Phosphates						Specific Conductance					
	Aug	Sept	Nov	Mar	Apr	May	Aug	Sept	Nov	Mar	Apr	May	Aug	Sept	Nov	Mar	Apr	May
Cushing Academy STP Ashburnham	2	10	4	4	2	3		.62	.16	.02	.12	.22	189	220	190	185	168	169
Clinton MDC STP					6												420	
Concord STP																		
*Marlboro STP East	<1	1		5	10		7.5	0.7		3.28	2.08		474	564		367	463	
Marlboro STP West	<1	30	3						.57				290	405	218			
Dracut STP			<1	1	3				.35	.08	0.19				70	72	252	
**Newburyport STP	5	<1	<1	7	10		7.8	6.85	5.6	2.76	3.56		72	1007	1995	720	610	
Shrewsbury STP		11	8	6	4			1.07	8.8	3.40	2.76			220	560	346	342	
Westboro STP	<1	45	3	30	32		.05	9.53	22	4.32	3.88						426	
Concord Reformatory STP			3		3				6.3		6.96				230		434	
Shirley STP	2		2	1	2		35.4		3.8	.44	1.23		425		218	246	327	

*Marlboro East STP was upgraded to tertiary treatment , March effluent reflects new plant in operation.

**Newburyport STP - December analysis showed the following metal concentrations: Chromium - 4.2 mg/l
Cadmium - 0.75 mg/l
Nickel - 0.49 mg/l

Table 5
Merrimack River Basin
Water Quality Analysis of
Wastewater Treatment Plants
With Discharges to Land Disposal

Station	Treatment Plant	Fecal Coliform / Total Coliform					Chlorides					Nitrates				
		Aug	Sept	Nov	Apr	May	Aug	Sept	Nov	Mar	May	Aug	Sept	Nov	Apr	May
50	Anna Maria College STP		0	0				45	52				70	70		
59	Mt Pleasant CC. STP	200			3500 / 8600	300 / 6300	50			29	15	55			28	34

have chlorination facilities but it is not in operation as can be seen from the bacteriological analysis. Anna Marie College treatment plant consists of subsurface sand filters, polishing filter and effluent chlorination.

2. Sludge Disposal

The disposal of waste treatment plant sludges in some areas is a major problem, especially where sludge is not incinerated. Sludge drying beds have created odors, objectionable to nearby homes.

The location of municipal plants are most often at the lowest practical geographical site in the community so that the collection system can be gravity feed. These low areas may consist of wetland areas. The low basic cost of acquiring this land (cost per acre) is attractive, but this type of land is not suitable for sludge disposal.

An investigation of the Shrewsbury treatment plant found that the sludge from this plant has been dumped in an adjacent swamp. Subsequent pollution of a nearby river resulted. Threats of court action from two towns whose areas included part of thses wetlands stopped further sludge dumping into the swamp. The sludge is now transported several miles to a sanitary landfill.

In older plants sludge drying beds were located adjacent to rivers or streams and were subjected to flooding and erosion. Any new plants are required to carefully consider the areas designated for sludge disposal to insure minimal environmental damage.

3. Collection Systems

The development of sewerage systems in the United States generally followed European practices; the main objective was to collect, transport and dispose of stormwater. The disposal of domestic, commercial and industrial wastes was the responsibility of the individual and discharge of such wastes into the storm sewers was prohibited.

When authorities lifted the ban, it was only natural that the large capacity storm sewers would be used to transport sanitary waste as well.

In the past, the significance of combined sewers, occasionally discharging directly into streams and lakes, was not recognized or considered to be of major importance. The excess flow from storm water, which overflowed directly into the receiving stream, was considered acceptable since the storm water would tend to dilute the sanitary waste and reduce the pollution load.

In a report by the United States Public Health Service in 1964, the following generalizations were made as to the characteristics of combined sewer flows:

a. The annual average combined sewer overflow volume represents approximately five percent of the total pollution discharged into the nations waters;

b. The average overflow from a combined sewer may contain from three to five percent raw sanitary waste; and

c. During storm peaks, as much as 95 percent of the sanitary waste may discharge directly into the receiving stream.

The dilution hypothesis failed to consider that setteable solids would settle out of the sanitary waste. When a storm occurred, these solids were resuspended. This observation resulted in a "first flush" hypothesis, where during the initial period of the storm the contaminated flow would be directed to a treatment plant and after a specified length of time the remaining flow would be discharged to the receiving water with little damage to the water quality. Figures 1 and 2 show that the only parameter which follows the first flush theory was phenols; all others show no decrease relative to elapsed time.

The Federal Water Quality Administration sponsored two studies, one was conducted by Burn, Krawczyk & Harlow, on the chemical and physical characteristics of combined and separate stormwater overflow for the Detroit-Ann Arbor Area. (4) Annual average values and the maximum value observed were given as follows:

Analysis	Annual Mean	Maximum Value Observed
BOD, mg/l	153	685
Sus. Solids, mg/l	274	804
Vol. S.S., mg/l	117	452
Sett. Solids, mg/l	238	656
Vol. Sett., Solids mg/l	97	376
NH_3-N, mg/l	12.6	134
Organic N, mg/l	3.7	38.4
NO_3-N, mg/l	0.5	2.8
Total PO_4, mg/l	14.6	43.2
Soluble PO_4, mg/l	7.7	21.2
Phenols, mg/l	312	8000

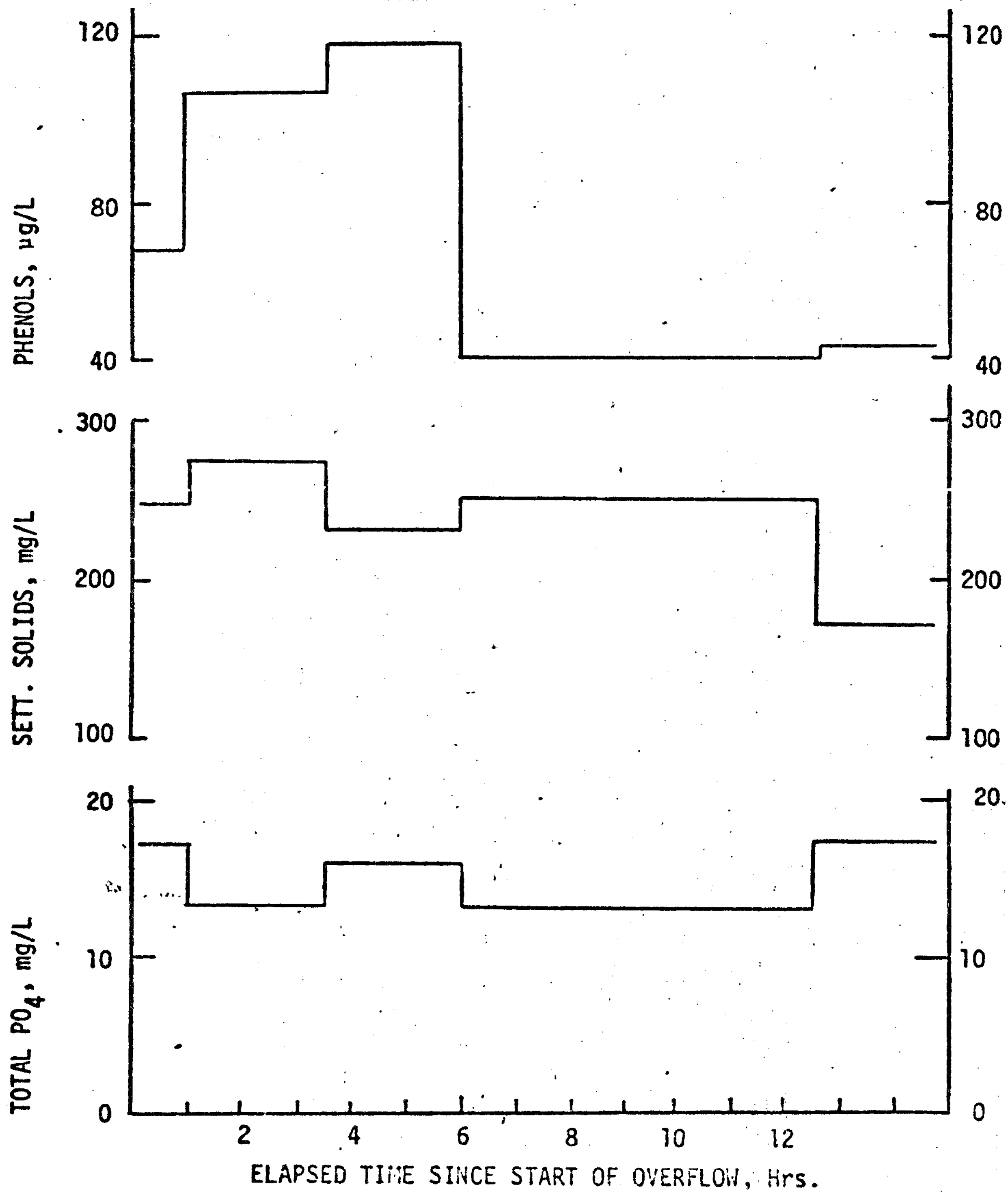


Figure 1 Variation of Qualitative Parameters throughout the Duration of an Overflow (4)

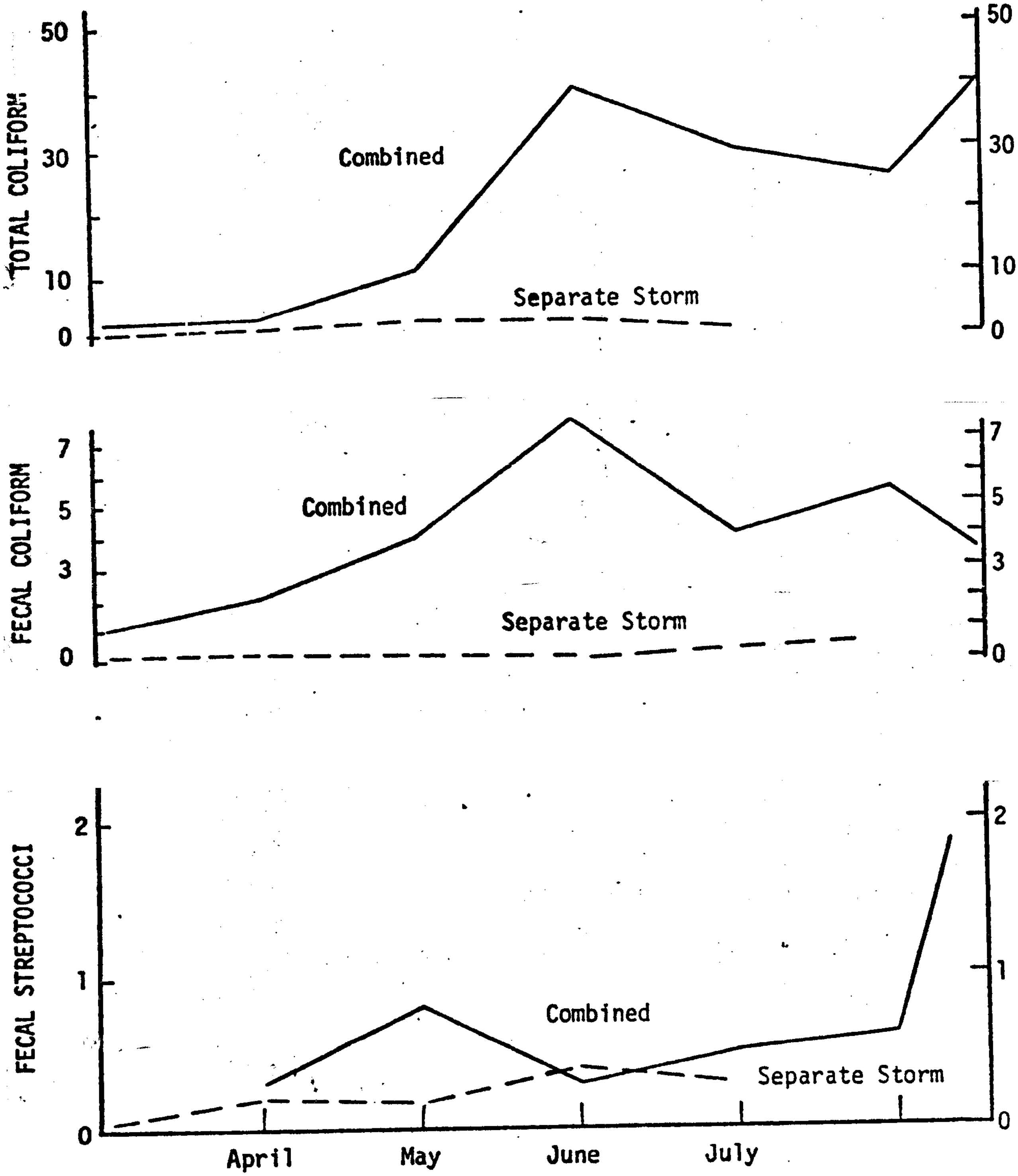
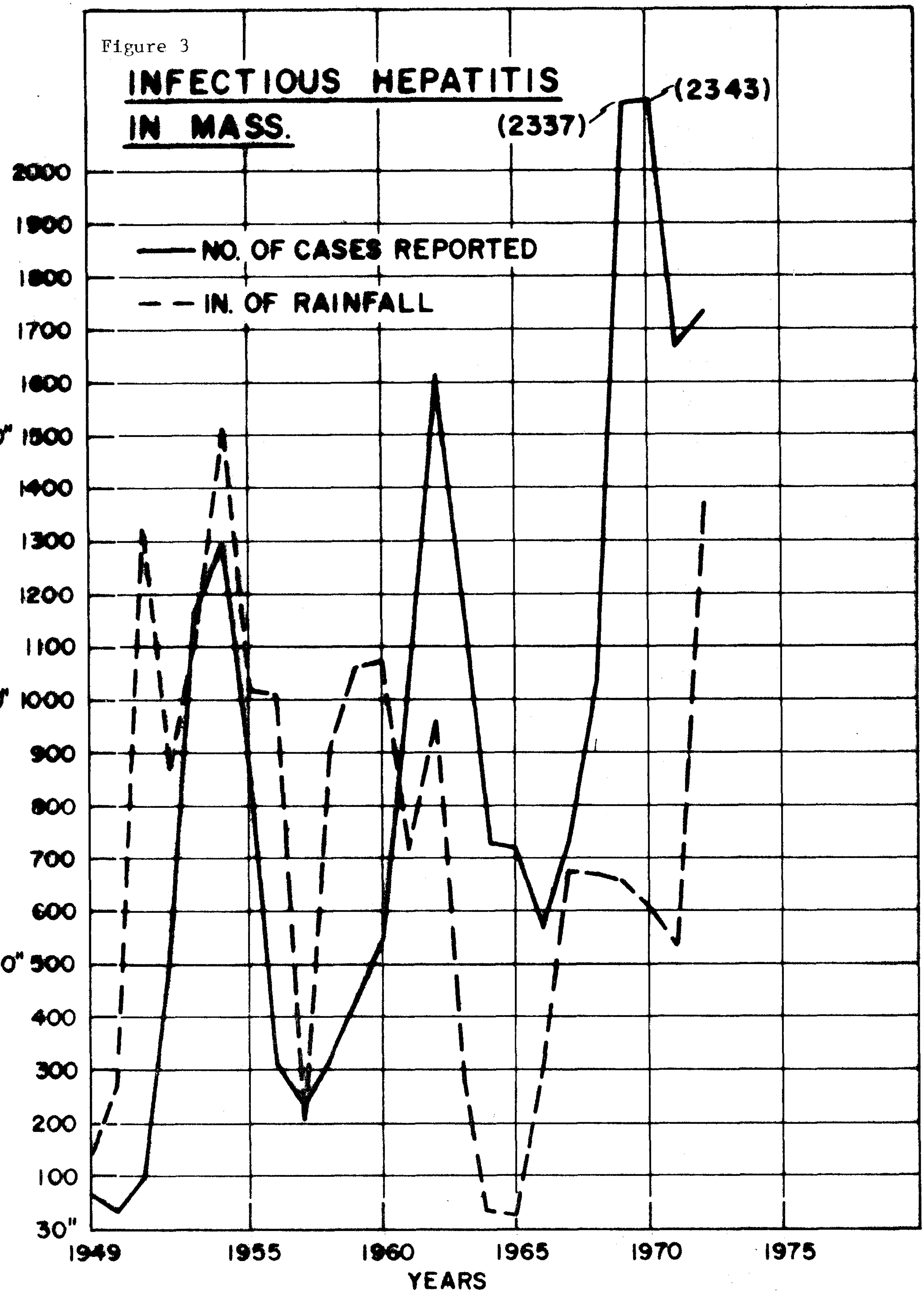


Figure 2 Seasonal Variation of Total, Fecal, and Fecal Streptococci in 10^6 mg/l for Overflows of Combined and Separate Storm Sewers. (4)

Figure 3



INFECTIOUS HEPATITIS IN MASS.
(2337)
(2343)
NO. OF CASES REPORTED
IN. OF RAINFALL
2000
1900
1800
1700
1600
60" 1500
1400
1300
1200
1100
50" 1000
900
800
700
600
40" 500
400
300
200
100
30"
1949
1955
1960
1965
1970
1975
YEARS

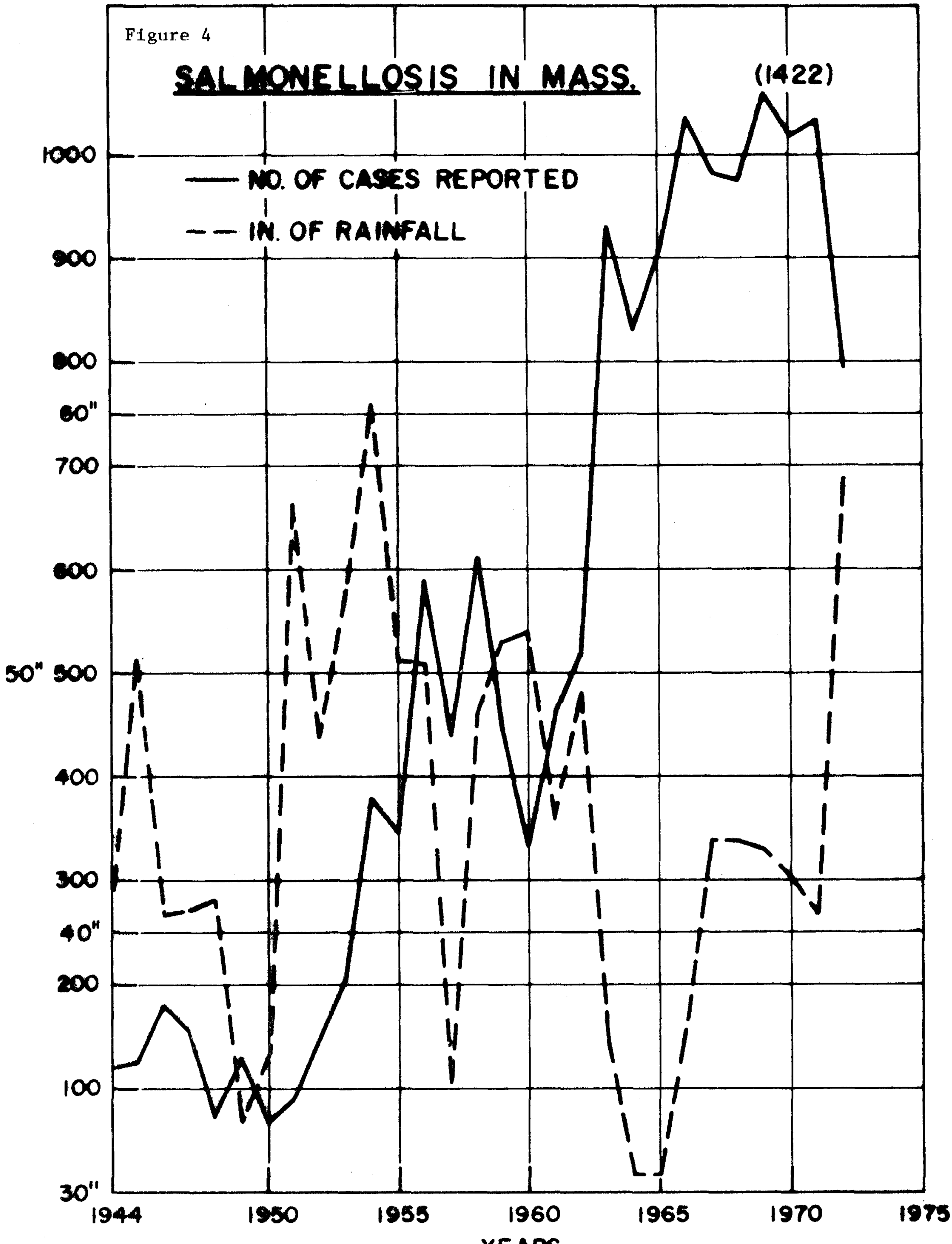


Figure 4
SALMONELLOSIS IN MASS.
(1422)
NO. OF CASES REPORTED
IN. OF RAINFALL
1000
900
800
60"
700
600
50" 500
400
300
40"
200
100
30"
1944
1950
1955
1960
1965
1970
1975
YEARS

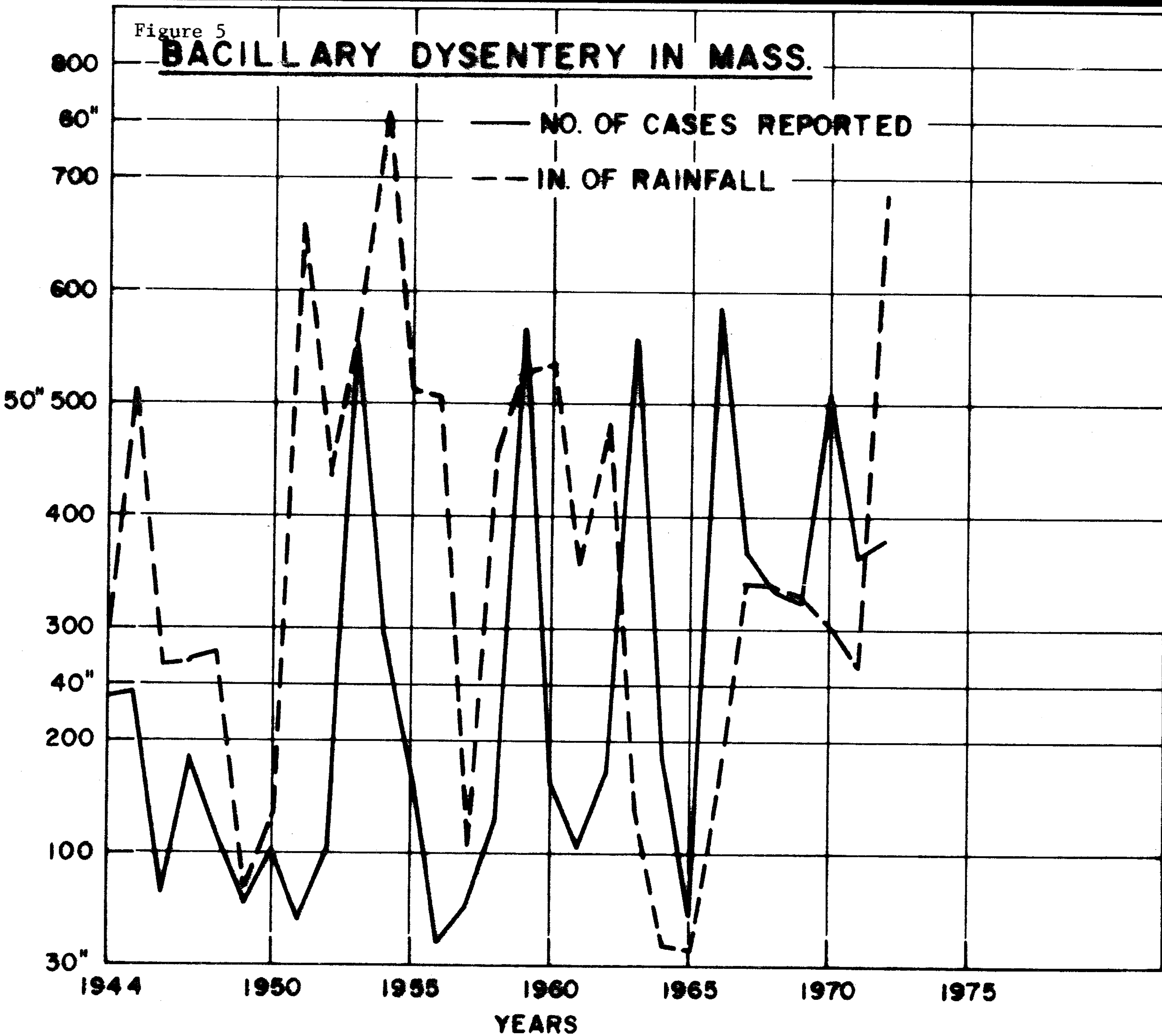


Figure 5
BACILLARY DYSENTERY IN MASS.
NO. OF CASES REPORTED
IN. OF RAINFALL
800
60"
700
600
50" 500
400
300
40"
200
100
30"
1944
1950
1955
1960
1965
1970
1975
YEARS

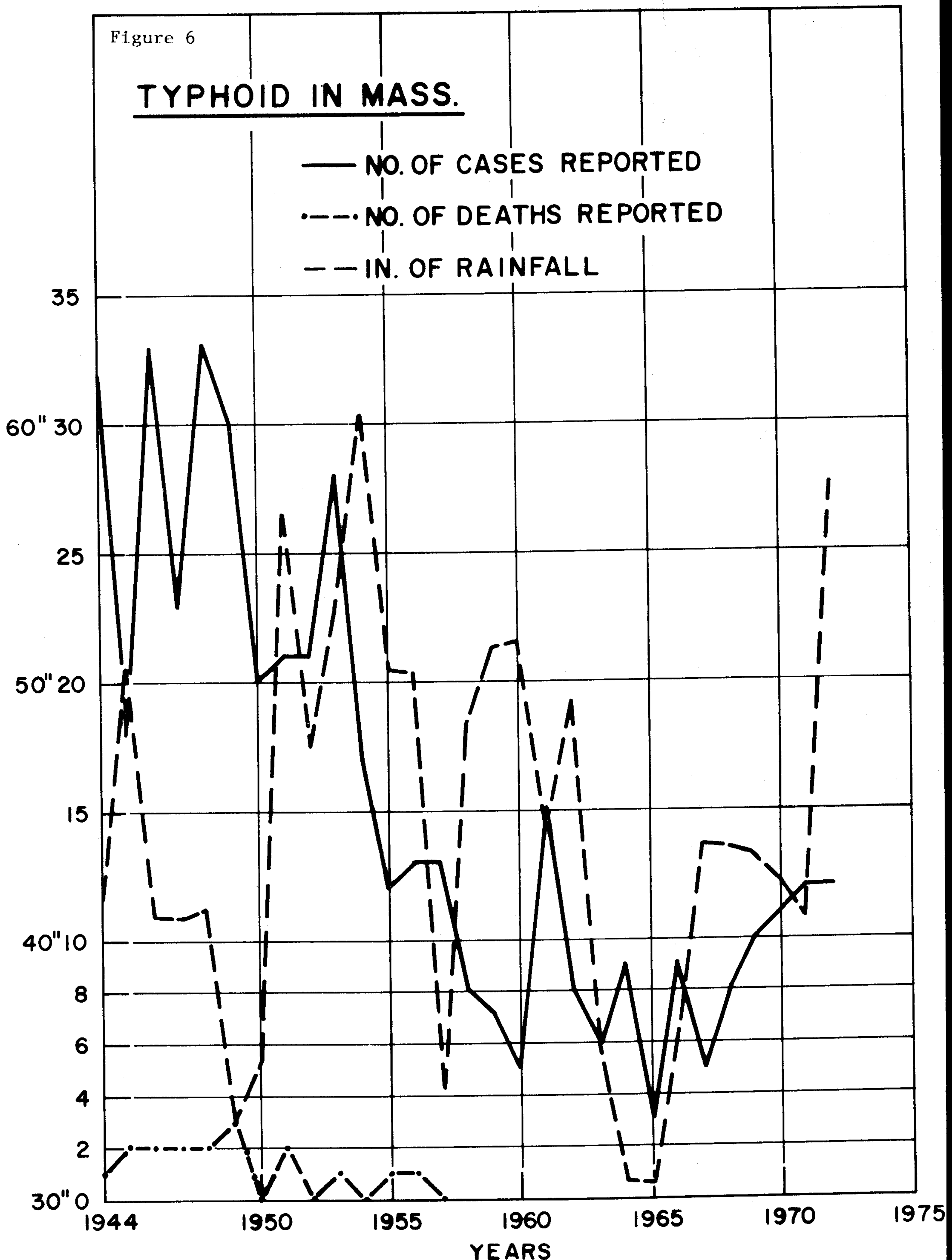


Figure 6
TYPHOID IN MASS.
NO. OF CASES REPORTED
NO. OF DEATHS REPORTED
IN. OF RAINFALL
35
60" 30
25
50" 20
15
40" 10
8
6
4
2
30" 0
1944
1950
1955
1960
1965
1970
1975
YEARS

Based on Figure 2, several conclusions were made as follows:

1. Total coliform densities may approach those found in raw wastewater;
2. The total and fecal coliform densities increased with the warm months, but fecal streptococcus counts remained relatively constant; and
3. Initial counts are about the same or slightly higher than the later counts, indicating that first flush effects were negligible.

From these reports, it is apparent that overflows from combined sewers can have high levels of pollution equivalent to that of raw sanitary waste. The effect of these overflows on the receiving stream were studied by Burn also, and his conclusions are as follows:

1. The effects of the discharges from combined sewers are felt for several days following the storm;
2. Coliform densities exceed 100,000/100 ml in a large amount of the receiving water after a moderate rain, and the counts may exceed 1,000,000/100 ml if the storm is unusually severe; and
3. Effects of the storm are negligible above the overflow discharges.

The quantity of combined sewer runoff is a figure which is recognized as being less than the total rainfall. This deficiency is attributed to the result of rainwater being retained on vegetation, infiltrating into the soil, wetting previous surfaces, being stored in depressions, and providing a film of water to allow flow. All of these factors contribute to a "coefficient of runoff," which for densely populated and build up areas of a city is estimated at 0.7-0.9 whereas in wooded areas may be as low as .4, the coefficient is then multiplied by the rainfall intensity to obtain the amount of runoff.

The runoff from separate storm sewers add additional loads to the receiving waters. Chlorides from winter salting practices, suspended matter, grit and oil and grease can all be collected by flowing stormwater and discharged into the receiving water. The runoff from storm drainage systems has resulted in chloride concentrations as high as 14,000 mg/l in one water supply feeder stream in Framininghan. Such densities can lead to reservoir stratification at depths shallower than normal. Such stratification may cause serious water quality troubles as well as alter the biological equilibrium because of the tolerance limits of some organisms to saline concentrations.

An interesting relationship was noted by graphically plotting the number of reported cases of infectious hepatitis, bacillary dysentery, salmonellosis and typhoid fever against rainfall for the years 1944-1974. Figures 3 through 6. The case data was obtained from the Massachusetts Department of Public Health Records. From the graphs there appears to be a correlation between increase rainfall and the number of reported cases of infectious hepatitis, bacillary dysentery and typhoid fever. The increase in reported cases of Salmonellosis does not follow the increase in annual rainfall.

Increased rainfall causes increased runoff, and increased pollutional load transportation from upstream source to downstream users. Increased transportation and velocity increases turbidity.

Increased annual rainfall raises the groundwater table and in turn increases the capillary fringe elevation of water from the phreatic surface to several feet depending on the type of soil over-lying the water table.

Individual land disposal systems located within the capillary fringe of the groundwater table are subject to overflow. When the inflow exceeds the percolation rate, the disposal system may overflow to the surface; into groundwater or streams; or backup into the house plumbing.

In some cases, increases in percolation rate due to rainfall also increases the travel distance and decreases the time of sewage effluent movement through the individual leaching area. Where individual wells are not protected by sufficient distances from pollution sources and are not sealed properly at the bedrock-soil interface, contamination may occur.

Another problem in sanitary sewers is infiltration. Broken pipes, poorly sealed pipes, pipes layed in the groundwater table, and poorly installed fittings at manholes all increase infiltration rates and cause hydraulic overloading at the treatment plant. Where excessive infiltration exists, the wet weather flow can exceed the design capacity of the plant by as much as 300 percent. Leakage of sewage into a water supply aquifer from a broken or poorly sealed pipe can cause contamination of this supply. Polluting materials discharged into or at the groundwater level do not degrade or are not adsorbed on the soil particles as is the case in a well-designed septic tank - leach field system. In addition, most groundwater supplies are not chlorinated and not monitored regularly hence contamination is not identified until illness results.

Thus, the problem of infiltration is two-fold; first it increases the flow to the treatment plant resulting in bypassing or poor treatment of the waste and secondly, sanitary sewage can seep out of pipe (exfiltration) into a water supply aquifer. Both cases could result in a potential health hazard.

In addition, throughout most sewer collection systems, there are lift stations. These pump stations are usually located adjacent to a water course. Old systems were designed such that overloading, power failures and/or mechanical failures resulted in bypassing the waste directly into the adjacent water course. The overloading can be due to high infiltration into the system or additional connections allowed in the system without additional pumping capacity installed. New facilities are required to install high water alarms and duplicate equipment. No bypasses are allowed in the design of the system. As failing lift stations are recognized immediate action should be taken to implement the new requirements on the old system to insure elimination of subsequent failures.

F. DISPOSAL OF SANITARY WASTES IN UNSEWERED AREAS

1. Individual Household Waste Systems

One of the potential sources of stream pollution and causes of waterborne disease is the failure and subsequent overflow of household on-lot land disposal systems. Instances of disease outbreak, such as occurred in Alaska; Keene, N.H.; and more recently in Vermont, have been traced to faulty individual land disposal systems, which contaminated the public water system. (9)

Thirty-nine cities and towns in the Merrimack River Basin were surveyed to determine the approximate number of on-lot wastewater disposal systems. Interviews with town officials such as Boards of Health, Water Departments, Director of Public Works, town clerks and officials of Regional Planning Commissions produced the data shown on Tables 6 and 7. Of the thirty-nine cities and towns surveyed, twenty-two towns used on-lot systems exclusively. Of the total population of 564,000 (1970 census), 312,000 or over 50% of the total population were served by individual on-lot land disposal systems. Based on town water consumption records and allowing 60 gallons per person per day, this amounts to about 12×10^9 gallons of sewage disposed of by land absorptive systems each year.

There are recorded subdivision plans on file with the Registry of Deeds showing over 600 house lots in one subdivision. Each home in this subdivision would be sewered by an individual land disposal system. Assuming an average of 3 people to a household, there would be a population of 1800 using individual waste systems. Assuming a water consumption of 60 gallons per person per day, the daily sewage flow would amount to 108,000 gallons to be absorbed into the subdivision soil each day.

These large wastewater volumes cannot be overlooked in the total wastewater management plan of the Merrimack River Basin. The proper design and installation of these individual systems are the essential criteria in preventing non-point pollution.

The design of individual disposal systems are of three main types:

1. Septic tank discharging to a leaching bed.
2. Septic tank discharging to a series of trenches.
3. Septic tank discharging to seepage pits.

The most common design used is the first, that of a leaching bed. The sizes vary with the soil absorption ability. For example, a percolation or soil absorption rate requiring 600 square feet could be provided by constructing a leaching bed either 20 X 30 feet; 10 X 60 feet; or 8 X 75 feet.

In the case of a trench design, the required absorption area could be made up of three trenches--three feet wide and about 66 feet long or three trenches two feet wide and 100 feet long each.

Table 6

	Percent Sewered	Sewer Per. Issued	Number of Connections	Gallons of Water Used	Population Sewered
Acton	0	114	-	425,000,000	-
Amesbury	70	22		463,885,300	7,971
Andover	50	137	3,500	1,108,779,000	11,847
Ashburnham	0	47	-	55,511,250	-
Ashby	0	22	-	Ind. Wells	-
Ayer	65	12	810	310,250.000	4,805
Billerica	18	110	1,144	1,203,681,000	5,697
Bolton	0	45	-	Ind. Wells	-
Berlin	0	20	-	Ind. Wells	-
Burlington	99.9	0	3,969	1,064,502,420	21,958
Carlisle	0	52	-	Ind. Wells	-
Chelmsford	0	89	-	883,707,640	-
Concord	40	7	1,221	456,250,000	6,459
Dracut	0	-	-	389,000,000	-
Dunstable	0	35	-		-
Fitchburg	85	13	11,000	2,898,100,000	36,841
Groton	0	69	-	551,150,000	-
Harvard	0	75	-	839,500,000	-
Haverhill	80	53		1,992,331,000	36,896
Holden	17.7	100	564	260,268,694	2,223
Hudson	74	51	3,039	1,197,420,000	11,902
Lancaster	0	40	-	178,850,000	-
Leominster	89	47	8,000	2,945,550,000	29,315
Lexington	99	8	7,000	No Information	31,547
Lincoln	0	15	-	136,451,070	-
Littleton	0	64	-	212,000,000	-
Lunenburg	0	86	-	102,200,000	-
Marlborough	80	28	5,042	1,263,000,000	22,349
Merrimac	0		-	88,310	-
Newburyport	90	12		882,390,200	14,226
North Andover	40	70	2,601	679,000,000	6,514
Rutland	25	NI	393	101,000,000	800
Shirley	0	32	-	73,000,000	-
Sterling	0	39	-	67,764,000	-
Sudbury	0	147	-	456,051,000	-
Tewksbury	0	224	-	655,052,390	-
Westford	0	134	-	251,046,800	-
Weston	0	63	-	443,820,000	-
Wilmington	5	161		958,051,000	855
		2,191		24,610,387,654	252,205

Water figures do not include Dunstable and Lexington.

Permits do not include Dracut, Merrimac and Rutland.

Table 7

	Gallons Sewered	Gallons to Ground	Population Not Sewered
Acton		425,000,000	14,770
Amesbury	324,719,710	139,165,590	3,417
Andover	554,389,500	554,389,500	12,118
Asburnham	-	55,511,250	3,484
Ashby	-	41,500,500	2,274
Ayer	201,662,300	108,587,700	2,588
Billerica	216,652,580	987,028,420	25,951
Bolton	-	34,766,250	1,905
Berlin	-	38,306,750	2,099
Burlington	1,063,437,918	1,064,502	22
Carlisle	-	52,395,750	2,871
Chelmsford	-	883,707,640	31,432
Concord	182,500,000	273,750,000	9,959
Dracut	-	389,000,000	18,214
Dunstable			1,292
Fitchburg	2,463,385,000	434,715,000	6,502
Groton	-	551,150,000	5,109
Harvard	-	839,500,000	13,426
Haverhill	1,593,864,800	398,466,200	9,224
Holden	27,848,878	232,419,816	10,341
Lancaster	-	178,850,000	6,095
Leominster	2,621,539,500	324,010,500	3,624
Lexington	614,117,939	6,203,211	339
Lincoln	-	136,431,070	7,567
Littleton	-	212,000,000	6,380
Lunenburg	-	102,200,000	7,419
Marlborough	1,010,400,000	252,600,000	5,587
Merrimac	-	88,310	4,245
Newburyport	794,151,180	8,239,020	1,581
North Andover	271,600,000	407,400,000	2,058
Hudson	886,090,800	311,329,200	4,182
Rutland	25,250,000	75,750,000	2,805
Shirley	-	73,000,000	4,909
Sterling	-	67,764,000	4,247
Sudbury	-	456,051,000	13,506
Tewksbury	-	655,052,390	22,756
Westford	-	251,046,800	10,368
Weston	-	443,820,000	10,870
Wilmington	47,902,530	910,148,450	16,247
	12,899,512,635	11,710,875,019	311,783

The third type, that of seepage pits an effective absorption area could consist of two pits with outside diameters of ten feet with an effective liquid depth below the inlet pipe of over seven feet.

The septic tank is basically a settling tank or a primary treatment process which results in a 15-30 percent reduction in the BOD loading entering the ground through the subsurface leaching unit. Although the septic tank performs a vital role in the primary treatment process by reducing the organic load, the size of the tank is probably of less value than the distribution system through which the effluent reaches the soil.

The soil's ability to absorb effluent is rated by the percolation test. This test has been devised to indicate the ability of the soil to continually absorb the discharge from the septic tank. Soils that fail to absorb sewage effluent result in back up of sewage in the toilets, sinks and laundry or an overflow on the ground surface in the area of the disposal systems. This overflow of sewage is a nuisance by definition because of the odor and may be a serious public health hazard by allowing possible pathogenic organisms to come in contact with the public. The abatement of such problems may require the installation of public sewers and treatment facilities. Millions of dollars are spent each year to sewer areas where on-lot systems have failed and nuisances or dangers to public health have resulted.

Soils are of many types in Massachusetts and have a wide range of absorption capacities. Soil types such as Hinckley and Merrimac (sands and gravels) have high percolation ability. Soils such as Paxton, Hollis and Charlton, have generally poor percolation ability with varying depths to hardpan, bedrock and to the groundwater table. The Hinckley and Merrimac soils have a greater ability for downward movement of water than the Paxton and Charlton types.

In Paxton type soil, a hardpan layer may exist 16"-30" below the surface. Individual sewage designs, therefore, should be based on the particular soil type and slope of the terrain at the site location.

One indicator of the type of soil and how well it absorbs water is the tree species growing on a particular site. Dense tree and brush growth are indicators of wet or moist soils throughout the year. Tree species, such as red maple, white and black ash, yellow birch, grey birch, and red oak, indicate wet conditions with clay soils near the surface. Sparse growths with trees of pitch pine and white oak usually indicate good percolating soils.

The U.S. Department of Agriculture, Soil Conservation Service has established guidelines for acceptable soils for the disposal of sewage effluent. These guidelines are in the Addendum to this report.

Studies and investigations carried out in the City of Glastonbury, Connecticut by M. Hill, Chairman, University of Connecticut Agricultural Experiment Station, showed that sewage systems placed in compact glacial tills has a median age of failure of 6.1 years (median age is a measure of the number of years in which 50 percent of the failing systems failed) whereas systems in stratified sand and gravel had a median age of 13.1 years. (13)

In order to prevent failures, Hill suggested the following design criteria:

1. Percolation tests and test pits should only be made in early spring, or at the time of highest groundwater levels; and

2. Designs made for sands and gravels should be of the same square footage area as for compact glacial soils.

There are many factors that cause system failure. Some are:

1. Location;

2. Percolation tests done on soils which subsequently were removed due to regrading;

3. A soil horizon has been intercepted by a cut in the original grade near the disposal area;

4. The bottom leaching area has been placed in the capillary fringe zone of the groundwater table.

5. Insufficient leaching area for the volume of wastewater.

6. Percolation tests conducted above the effective area of effluent discharge; and

7. Ion exchange capacity of the soil is too high, thus resulting in Na^{++} and Ca^{++} ion exchange. (The replacement of Ca^{++} ions with Na^{++} ions results in soil deflocculation).

A report by Minear & Patterson states "it is the opinion of most public health engineers that a septic system is generally an unsuitable waste disposal technique." They state further that "septic systems used frequently results in contamination of the soil, surface and groundwaters, and thus constitutes a public health hazard." (24)

The Minear & Patterson report fails to note the percolation rate or the elevation of the groundwater table in their study areas. A review of the soils in Lake County and Will County in Illinois show that percolation rates range from 15 minutes to over 75 minutes per inch, with groundwater elevation varying from one foot to three feet below grade. The installation or operation of subsurface on-lot systems placed in such soils and in or near the groundwater table are assumed to fail.

Massachusetts Department of Public Health places an upper limit for the percolation rate of 30 minutes per inch. The U. S. Public Health Service recommends a maximum of 60 minutes per inch. Massachusetts regulations further requires a distance of a 4 foot "freeboard" between the bottom of the disposal bed and the top of the groundwater table.

The location of the ultimate disposal site is also very important. The Massachusetts Department of Public Health regulations require a minimum distance of 100 feet from the leach field of a sewage disposal area to any surface water supply or tributary to a water supply. For other water courses the minimum distance is 75 feet for a single dwelling and 100 feet for a mutiple dwelling. The Sanitary Code recommends that an additional adequate area for the disposal of the effluent be reserved for reconstruction or expansion of the system. This is only a recommendation not a regulation and has little or no enforcement power. Zoning laws, which contain the power to regulate lot sizes and restrict the type of dwellings being built should take into consideration the type of soil and its ability to absorb the total wastewater generated from a particular type of dwelling.

Field investigations made in this study reveal the encroachment of individual sewage disposal systems to water courses, where pollution of that water course may be considered a point or non-point source of pollution. The authority of the many local Boards of Health to control recommended distances is at best haphazard.

It would seem in the best interest of economics and the public health that individual household systems should have a life expectancy of at least 20-25 years with a reserve land area for the construction of a new land disposal area following the failure of the original system from soil clogging.

Dr. Bauma, University of Wisconsin, believes there is a sq. ft. area of disposal in certain soils where the inflow-outflow reaches a steady state condition. (3) In this situation, failures will not likely occur.

Field investigations in the Merrimack River Basin show that many disposal systems have functioned properly for 20 years. The disposal areas of these systems in a subdivision range from 1,000-1,200 sq. ft.

The cost of a 1,200 square foot leaching area would be about \$1,000 and would have an estimated service life of 20 years. The depreciation for this system would amount to \$50/year. In comparison, a 600 sq. ft. leaching area with a service life of 5 years would need 4 replacements within this 20 year period at a depreciation of \$162/year. The following claculations outline how this cost was derived; an inflation rate of 3 to 5% per year was assumed.

Years in Service		Cost	Inflation/year
0-5	initial system	$ 600	
5-10	2nd system	690	3%
10-15	3rd system	862	5%
15-20	4th system	1078	5%
	Total Cost	$3230	
	Cost/year	$ 162	

Thus, the comparison cost of $50/year for a 1,200 sq. ft. leaching area to $162/year for a 600 sq. ft. area is one third the yearly cost. This does not take into account the cost to reseed lawns and other added costs of area damage due to construction of each system, nor can the public health hazard of exposure be calculated.

Observations of individual homes under construction show that often the house is placed on the best available area on the lot. The disposal system is then placed in the least desired location in regard to soil percolation ability and expansion. The average three bedroom home will discharge an average of 100,000-110,000 gallons of sanitary sewage per year. Soils unable to absorb this volume year after year result in system failure.

The volumes of wastewater discharged into the ground from individual systems is significant. In some areas, this steady state flow into the ground may play an important role in the recharge of local groundwater wells. Chelmsford has all individual land disposal systems. The total water consumption in the town in 1972 was 864 million gallons. It can be assumed that a portion of the sewage effluent from some 10,000 homes, industries and businesses is entering the groundwater table. Chelmsford issues approximately 200 individual sewer permits each year either for new construction or repairs to existing systems. Implementation of the proposed alternatives in sewering most of Chelmsford will help to control pollution of the groundwater and local streams but will not serve as a recharge source for groundwater. Such loss of groundwater recharge may effect the availability of groundwater as a water supply in future years.

The present state sanitary code for individual disposal systems does not include regulations governing proper land-use management techniques, minimum house lot size, or minimum land area for the disposal system. The code contains some recommendations that are not always implemented. Since sewage system failures have occurred and are occurring throughout the Merrimack Basin, it appears that either the code is not strict enough or that its implementation is weak or nonexistant.

Based on the performance of individual systems to date, there appears to be a need of a complete evaluation of the sewage system beginning at the septic tank to determine the most efficient design for effluent discharge especially in regard to BOD and suspended solids removal. The land area required for final effluent disposal is customarily determined by the percolation test. There appears to be questions of determining the true rate of percolation under certain soil testing conditions. Hill suggests that recorded rates on record do not agree with true rates. Is a percolation rate of 1 inch in 10 minutes a true operational rate for soils with an impervious zone 3-5 feet below grade? Secondly, can complete soil saturation be achieved under artificial soaking in determining percolation rates? The size of leaching areas are calculated on the bottom leaching area as determined by the percolation rate. It appears that lateral water movement should be considered in such designs and larger leaching areas required, if necessary. For example, a leaching area 23' x 23' equals about 529 sq. ft. as a bottom percolation zone for a percolation rate of 1" in 20 minutes, as shown under the State Sanitary Code. However, if the movement of sewage effluent is in a lateral direction, due to lenses or stratas below the disposal area, then the percolation or absorption zone is basically limited to the peripheral zone of: 23'+23'+23'+23' x 1' equaling about 98 sq. ft. (1' is the assumed normal vertical zone between the bottom of the leaching area and inlet of the sewage distribution pipes). Based on a sewage flow into the leaching area of 300 gallons per day and the sq. ft. bottom area of 529 sq. ft., the effective loading rate is 1.76 square feet per gallon. If the sewage effluent flow in the surrounding soil is lateral in movement then the effective loading rate is 0.33 sq. ft./gal. not 1.76 sq. ft./gal. The standard loading of 1.76 sq. ft. per gallon for this 20 minute soil would be reduced by nearly 4 times, and failure would be evident.

It would suggest that research should be funded to determine optimum designs for various soils. The present guidelines tend to leave too much to guess work and experience. The State of Maine now requires 1,000 square feet of leaching area for slight to moderate soil limitation. No mention is made of the percolation rate required. Soils in the slight limitation are defined as "rapidly permeable and occur on 0-8% slopes. They do not have layers within 5 1/2 feet of the surface that retard the downward movement of water." Moderate limitation soils also are "rapidly permeable and have formed in sandy and gravelly materials, but they occur on 8-15% slopes." Maine also requires a 20,000 square feet lot with a minimum of 100' frontage. Smaller lots may be used subject to approval in writing by the Board of Environmental Protection.

Massachusetts Federation of Planning Boards, publication entitled "Planners Handbook" list recommended lost sizes for homes located on various soil types. Minimum lot sizes for homes serviced by individual sewage system is 20,000 square feet, with lot sizes to 60,000 recommended for some soils.

In most cases, soils listed under the <u>severe limitation category</u> are not recommended for land disposal of sewage effluent.

Environmental officials and town planners recognize the need for minimum area for on-lot land disposal with acceptable soils.

Many towns, such as Berlin, Massachusetts, have the majority of the town with severe soil conditions. On-lot disposal in these soils would result in many system failures. System size, design, location, construction and maintenance appear to play an important role in any proper on-lot disposal. It may well develop that towns having no central sewerage system must limit housing to the absorptive capacity of the available soil.

The BOD_5 reduction in the septic tank may range from 15 to 30%. Maximum removal generally occurs when a 24-hour retention time is maintained in the tank. Failure to pump the accumulated solids from the tank at least once in 2 to 3 years will cause a reduction in the removal efficiency of BOD in the effluent. The frequency of tank pumping cannot be left to the individual home owner, since homes change ownership frequently. Today, the practice is to pump out the tank only after failure occurs. The increased load of BOD_5 and suspended solids entering the disposal field will decrease the soils ability to treat the effluent.

The disposal of the sludges pumped from these septic tank systems creates an additional problem. It is estimated that 29 to 35 million gallons per year are pumped from septic tanks and cesspools within the Merrimack River Basin. The Nashua River Program Tank Force Committee on Septic Tank Sludges and Solid Waste Sites estimate that 10,000,000 gallons per year will be pumped from on-lot disposal systems within the Nashua River Basin alone. This amounts to 500,000 lbs. of BOD

Common practice is to dispose of this material at the local dump or sanitary landfill. This could cause odors, a breeding site for bacteria, and contamination of nearby streams or groundwater due to run-off and percolation. These sludges have very high BOD loadings varying up to 18,000 mg/1 with COD loadings much higher. Such wastes cannot be pumped into an existing municipal treatment plant as a load dump, but if facilities are adequate, can be bled in slowly. The Marlboro East Sanitary Treatment Plant accepted over 200,000 gallons of septic tank sludges during September, 1974 and minor upsets in the operation of the plant resulted. The problem of transporting this sludge to the treatment system adds additional costs. Incineration of the sludges is another disposal alternative. This minimizes the health and safety hazards of the sludge but adequate air pollution devices must be installed to eliminate creating another health hazard. Local Boards of Health have jurisdiction over the disposal of such wastes and should keep strict control over the problem. Figures 7 and 8 show sludge drying beds and septage lagoons.

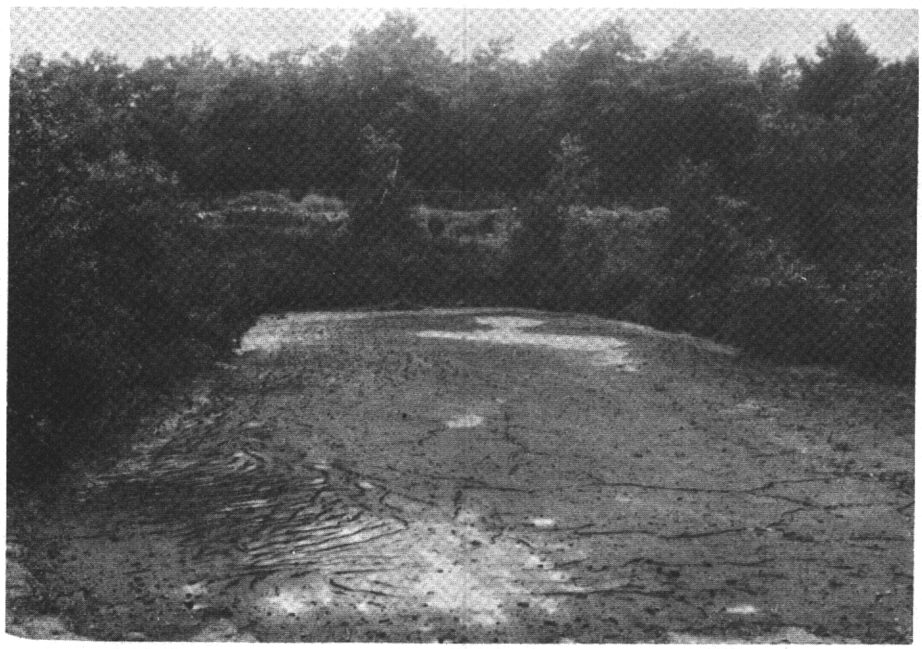
Section 104 of the FWPCA, Amendments of 1972, calls for a comprehensive research, investigation and pilot plant work on new and improved methods of preventing, reducing, storing, collecting, treating, or otherwise elliminating pollution from sewage in rural and other areas where collection of sewage in conventional, community wide system is impractical, uneconomical or otherwise unfeasible or where soil conditions or other factors preclude the use of septic tank and drainage field system. Once this needed research is completed implementation of the improvements must follow immediately to help solve this problem before any further damage is done to the environment.

Figure 7

Sludge Drying Bed

Acton, Massachusetts

(Septage Sludge)



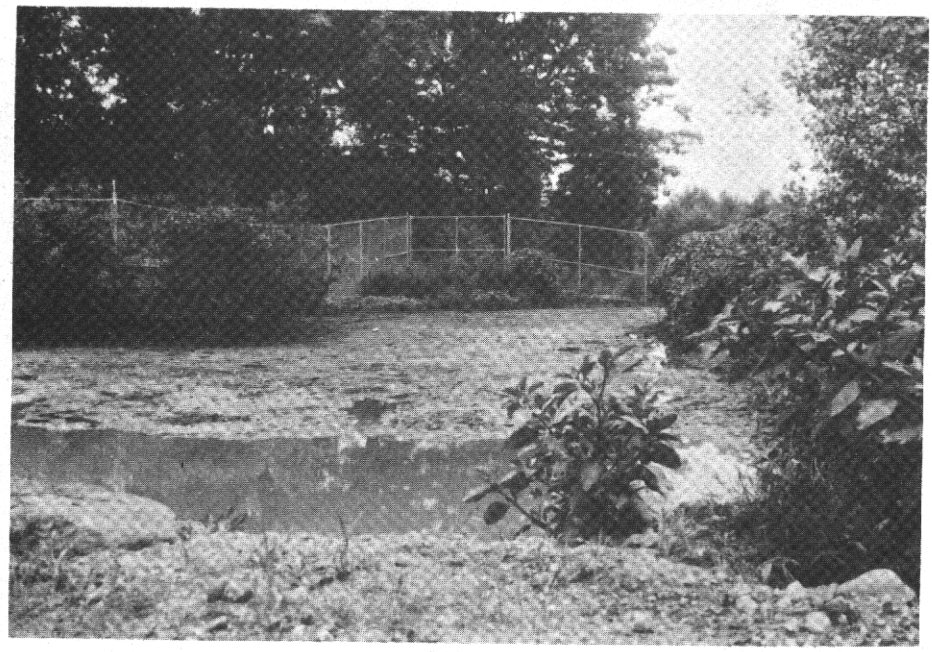
Septage is dumped at the far upper end of the picture and flows through collection pipe to the lower drying bed shown in the foreground.

Figure 8

Septage Lagoons

Acton, Massachusetts

Pumping from Septic Tanks and Cesspools



This lagoon is located in unconsolidated sand and gravels. The lagoon is at its maximum elevation.

Great numbers of mosquitos were present. This is an ideal media for mosquito production.

2. <u>On-Lot Land Disposal for Apartment and Condominiums and Other Large Water Users</u>.

With the change in housing construction from single family to multi-family units, sewage disposal by land application has taken on a new dimension. One of the most urgent problems in wastewater management is the proper disposal of these large volumes of sanitary wastes.

Apartment and condominium complexes and other housing units have been built and will continue to be built in areas without public sewers. There is a growing demand for these large concentrated units to be built adjacent to surface waters including public water supplies and feeder streams. Concern has been expressed at interviews with town and city engineers and other public works and health officials of the increased pollution generated by these systems, when failure occurs, and the potential source of infection to downstream water users.

Some streams flowing past these housing areas have strong septic odors. These conditions exist at Beaver Brook in Boxboro and Nagog Brook Tributary in Acton. (See tables for additional data). Both these towns have many housing complexes.

Many local health officials report sewage disposal system failures within two to five years after installation. Nashoba Associated Boards of Health report continuing problems of failure with large on-lot systems at nursing homes, apartments, condomuniums, and restaurants.

The Town of Acton has a large number of condomuniums and apartments served by land disposal systems. The health director reports that 75 per cent of these waste systems fail within two to four years after installation.

The problem of disposal suggests that the present land disposal designs are inadequate for large volumes of wastes. Disposal areas also appear to be limited and expansion areas are not available on the existing site. Observation of the disposal site shows that many systems have been installed in areas of high groundwater or in areas of questionable soil percolation ability.

Some failures are attributed to decreases in the movement of the effluent out of the initial disposal area and the development of chemical clogging substances generated under septic condition. Percolation tests conducted in the actual disposal area appears inadequate. Poorer percolation soils some distance from the parent bed may act as a dam, thus the liquid flow from the initial area may be greater than the percolation rate in the poorer receiving area. Insufficient consideration is given in the design and location of these large systems to the movement of the waste liquid from the parent area.

The situation is also critical from a social and economic basis. Odors from a large failing system are very offensive. Many large systems with flows of 10,000 - 15,000 gals/day may cost up to $150,000 or more. Continued failures and replacements are uneconomical in the first place and a burden to condominium owners and apartment dwellers because of increases in maintenance costs and increases in rent. The failure to maintain a certain quality effluent at a municipal sewage treatment plant with an outfall to a stream or river does not result in rebuilding a new treatment plant. In the case of subsurface land disposal systems, however, failure to maintain an optimum effluent quality will cause premature soil or media clogging and a new land disposal system is required.

The basic design as presently and commonly installed consist of a septic tank with a liquid volume 50 per cent larger than the daily estimated wastewater flow. The effluent-disposal designs are subsurface disposal into so-called ameration chambers or flow diffusion chambers or stone leaching beds. The design of the ameration chamber and flow diversion systems consist of concrete bridges set on 24" to 30" of sand. The effluent is applied by pump or gravity from the septic tank to the chambers. The effluent percolates through the sand media to the parent soil. The chamber sand media acts as a secondary treatment before the effluent reaches the original soil. The design of these chambers area are generally based on an application of one square foot of surface area per gallon of effluent applied.

Figure 9 shows the reconstruction of a clogged system at an apartment complex in Acton. The failed system is being reconstructed in the same location as the former system.

Thus, it appears that the larger on-lot systems have not performed well and design changes should be made. Research should be immediately begun to determine the causes of failure and the design criteria necessary to extend the life of these systems. The evaluation of the many field investigations and conferences with qualified officials conclude that the Federal government must take a lead in funding this research.

The present institutional structure does not provide the direct Federal-state-local authority, regional or Basin Area Authority to formulate wastewater management and control, and to enforce this policy. U.S. Environmental Protection Agency has authority limited to point source discharges. The Massachusetts Division of Water Pollution Control Authority appears limited to stream discharges and direct groundwater discharges. The Massachusetts Department of Public Health regulates land disposal systems which treat wastewater volume over 2,000 gal/day. The local boards of health have authority over individual land disposal system with wastewater flows less than 2,000 gal/day.

Some local health officials voice concern over the large number of large land disposal systems installed in their respective area. They voice the concern over lack of reserve area available when the present disposal system fails in a few years. Many officials question the approval of systems in fill or adjacent to swamps and streams and on side hills. However, their authority is limited to secondary approval of a previously approved plan.

Figure 9

Apartment Complexes

Apartments were built in a low elevation area adjacent to a feeder stream. The excavation shows high groundwater conditions.

The original waste disposal on-lot system had failed. The picture shows the reconstruction of the same area.

Increased cooperation and improved institutional structures at Federal, State and local levels, adopting research developments in design criteria and overseeing installation, operation and maintenance procedures should eliminate pollution sources from land disposal systems and decrease the public health hazards associated with failing systems.

G. EVALUATION OF SOLID WASTE DISPOSAL SITES

The location of solid waste disposal sites in the past have been on land generally unsuited for any other use. These dumps were placed in swamps, in the groundwater table, and along streams and rivers.

Low pH water usually found in swamps results in the ionization of metals. These dissolved metals result in pollution of groundwater and surface streams.

Camp, Dresser and McKee, Consulting Engineers, report the water analysis from a brook flowing through the Leominster municipal dump as: (6)

COD	165 mg/1
BOD	21 mg/1
pH	6.9
Alkalinity	320 mg/1
S.S.	700 mg/1
V.S.	315 mg/1
Iron	50 mg/1
Manganese	2.0 mg/1

Massachusetts has out-lawed open-faced dumps, but this has not changed the location of many dumps. One community in Massachusetts uses a river as the dumping ground for solid wastes and calls this site a "sanitary landfill".

A Camp, Dresser and McKee report lists several dumps located near rivers or streams. Among these are the Leominster dump near the North Nashua River, the Fitchburg-Westminster dump along Flagg Brook, the Town of Shirley dump located in the groundwater table and near Catacoonamug Brook and the Town of Groton dump on the Nashua River. The Nashua River flows into the Groton dump during high flows. The Lunenberg dump located near Mulpus Brook creates serious pollution problems. Local residents complain that their shallow wells have been contaminated by the dump leachates.

Table 8 shows the water quality data of eleven feeder streams which are adjacent to or flow through solid waste sites in the Merrimack River. These sites show non-point and point sources of chloride, iron and manganese pollution.

Table 8
Merrimack River Basin
Solid Waste Disposal Sites
Water Quality Data 1973 – 1974

Station	Water Source	Total Coliform Aug	Total Coliform Sept	Total Coliform Nov	Total Coliform Dec	Total Coliform Jan	Total Coliform Mar	Total Coliform Apr	Total Coliform May	Fecal Coliform Aug	Fecal Coliform Sept	Fecal Coliform Nov	Fecal Coliform Dec	Fecal Coliform Jan	Fecal Coliform Mar	Fecal Coliform Apr	Fecal Coliform May	Chlorides Aug	Chlorides Sept	Chlorides Nov	Chlorides Dec	Chlorides Jan	Chlorides Mar	Chlorides Apr	Chlorides May
2a	Locke Brook Trib Ashby Dump		0				40	120	0		0				1	0	0						<10	12	20
3	Flanagan Pond Ayer Dump		640	10		90	10	3200	20		190	2		4	0	210	0		270	80		100	165	28	240
9	Canal East Billerica Dump	230	750	50						42	20	25						90	90	72					
10	Canal West Billerica Dump	170	4400	80						41	65	8						90	65	150					
23a	Crystal Spring Brook Hudson Dump					5								0								120			
25	Elizabeth Brook Harvard Dump	300	70	63						96	22	25						225	40		29				
28a	Fish Brook Andover Dump																				60				
42	Second Div Brook Maynard Dump	190	1	101		6	1	56	300	0	0	21		0	0	7	250	80	30	25		24	32	25	25
47	Black Rock Creek Salisbury Dump		1600	270							15	1							15000	3700					
54	N. Nashua R. Leominster Dump	130	1900	2600			0	5400	1100	0	2	260			0	600	22	31	42	48			74	27	70
66b	Trib to Squannacook R Townsend Dump						430								20								43		

Taple 8 (Cont.)

Station	Specific Conductance Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
2a						80	158	122
3		2120	528		1545	1434	206	1224
9	510	415	418					
10	530	446	608					
23a					1620			
25	956	225		196				
28a				325				
42	530	307	270		230	255	221	202
47		37,875	14,175					
54	404	273		466		480	161	376
66b						358		

Station	Nitrates Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
2a						<1	<1	<1
3		1.0	1.0		4.0	7	3	6
9	<1	15	2					
10	9	<1	8					
23a					<1			
25	<1	<1		<1				
28a				1.0				
42	1	5	7		8	7	8	8
47		1	1					
54	1	1		1		3	2	3
66b						30		

Station	Phosphorus Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
2a						.01		.01
3		.01	<.01		0.05	0.06	0.04	.01
9	<.01		0.01					
10	0.01		<0.01					
23a								
25				<.01				
28a				.01				
42	0.01		<0.01					
47		0.26	0.05					
54	4.7	0.02		0.07		.02	<.01	.01
66b						.05		

Station	pH Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
2a							7.1	7.6
3		7.2	7.2			8.0	7.1	
9	7.2	6.5						
10		7.0						
23a					6.4			
25	6.8	6.9		6.6				
28a				7.0				
42	7.6	7.4	7.2		6.6	6.6	7.2	7.3
47		6.6	6.8					
54	7.4							
66b								

Table 8 (Cont.)

Station	Color								Chromium							
	Aug	Sept	Nov	Dec	Jan	Mar	Apr	May	Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
2a						13	10	15							0.00	
3		30	8			12	7						0.0			
9	23	10								0.0	0.0					
10		13								0.0	0.024					
23a					7								0.0			
25	33	30		13					0.0	0.0						
25a				5												
42		12	12		3	7	6	3			0.0		0.0	0.0	0.0	0.0
47		>50	>50								0.034					
54	>50											0.0				
66b																

Station	Silver								Copper							
	Aug	Sept	Nov	Dec	Jan	Mar	Apr	May	Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
2a							0.00								0.009	
3					0.013								0.042			
9		0.0	0.0							0.008	0.053					
10		0.0	0.01							0.008	0.061					
23a					0.0								0.077			
25	0.0	0.0							0.044	.008						
25a																
42			0.0		0.0	0.0	0.0	0.0			0.0		0.35	0.014	.009	0.03
47			0.037								2.2					
54				0.0								0.22				
66b																

Table 8 (Cont.)

Station	Manganese Aug	Sept	Nov	Dec	Jan	Mar	Apr	May	Lead Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
2a							1.9								0.00	
3					1.8								0.034			
9		0.12	0.34							0.00	0.00					
10		0.46	0.13							0.00	0.00					
23a					20.5								0.00			
25	0.32	0.094							0.00	0.00						
28a																
42			0.47		0.0	1.1	0.39	0.35			0.0		1.2	0.15	0.0	0.0
47			0.086								0.051					
54				0.44								0.00				
66b																

Station	Iron Aug	Sept	Nov	Dec	Jan	Mar	Apr	May	Cobalt Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
2a							10.5								0.00	
3					5.9								0.025			
9		0.36	0.62							0.00	0.00					
10		0.75	0.43							0.00	0.00					
23a					58								0.00			
25	0.34	0.57							0.0	0.00						
28a																
42			1.5		0.0	4.1	2.2	2.0			0.0		0.0	0.012	0.0	0.0
47			0.31								0.039					
54				4.9								0.013				
66b																

Table 8 (Cont.)

Station	Cadmium Aug	Cadmium Sept	Cadmium Nov	Cadmium Dec	Cadmium Jan	Cadmium Mar	Cadmium Apr	Cadmium May	Zinc Aug	Zinc Sept	Zinc Nov	Zinc Dec	Zinc Jan	Zinc Mar	Zinc Apr	Zinc May
2a							0.00									
3					0.00								0.34			
9		0.00	0.00							0.04	0.042					
10		0.00	0.00							0.072	0.165					
23a					0.0								0.28			
25	0.0	0.00							0.032	0.012						
28a																
42			0.0		0.0	0.0	0.0	0.0			0.057		0.02	0.1	0.13	0.07
47			0.019								0.33					
54				0.002								0.15				
66b																

Station	Nickel Aug	Nickel Sept	Nickel Nov	Nickel Dec	Nickel Jan	Nickel Mar	Nickel Apr	Nickel May	Turbidity Aug	Turbidity Sept	Turbidity Nov	Turbidity Dec	Turbidity Jan	Turbidity Mar	Turbidity Apr	Turbidity May
2a																
3					0.00											
9		0.00	0.00							.8						
10		0.00	0.00							1.2						
23a					0.0								.44			
25		0.00							.85	.75						
28a																
42			0.0		0.0	0.012	0.0	0.0			2.5		2.8	5.3	3.0	2.5
47			0.1													
54				0.014												
66b																

The Town of Maynard dump (Station 42) is located in an old gravel excavation site, which extends into the groundwater table. Filling of this hole with solid waste has resulted in pollution of a nearby pond and stream. High nitrates iron and manganese can be seen in the water quality analysis of Second Division Brook.

A similar problem exists in the Town of Andover where solid wastes were placed into the groundwater table. Within a few years, a nearby well was polluted along with a large area of an adjacent swamp.

Sanitary sludges from septic tanks are deposited at the Salisbury dump, Station 47. This site contains numerous salt marsh ditches which flow to beaches and Black Rock Creek.

Station 23a, Crystal Spring Brook at the Hudson Dump showed the highest levels of manganese, 20.5 mg/l and iron, 58 mg/l.

In order for the metals or other leachates to travel to a water course or into the groundwater, three essential conditions must be present:

1. The upper soil must be permeable for water infiltration;

2. There must be enough interconnecting voids in the soil to allow water to circulate;

3. There must be a topographic high area of recharge and a lower area of discharge.

In Massachusetts, with an annual rainfall of about 45 inches, the formulation and discharge of leachate from a site may be a greater hazard than in regions of little rainfall. Thus, in Massachusetts, the major problem is the prevention and control of leachates and the proper location of the disposal sites. Management is the answer to pollution control of the groundwater and surface waters.

It is estimated that in New England only ten percent of 17,000 land disposal sites meet minimum solid waste disposal regulations or criteria. In Massachusetts, only a few sites meet present-day requirements for refuse disposal. Eighteen of the existing 23 solid wastes sites in the Massachusetts portion of the Nashua River Basin are causing groundwater or surface water pollution. (26)

Control of this pollution can only be made possible by relocation of many present dumps and the removal of abandoned dumps that have been place in the groundwater table and which are serious threats to future groundwater supplies. Observation wells should be drilled around these sites to determine the extent of the polluted zone.

All untreated septic tank sludge must be kept out of present dumps and sanitary landfills, since the presence of large volumes of water can only add to the movements of leachates through the soil.

Future site location must be planned based on sound sanitary engineering. The placing of sanitary landfills in coarse sands and gravels only adds to the pollution problem. Because of the abundance of rainfall, water flowing from a refuse site must be kept to a minimum. This involves sound drainage designs and an absorbant final cover that will retain high amounts of water from precipitation.

Public and private water supplies are the main public health concern. Where sites are used for refuse alone, there is little evidence of bacterial pollution that would endanger recreational waters. Aesthetically, waters can be made unusable as occurred in the Town of Maynard by iron and manganese leaching.

A Federal and State program of solid waste site evaluation of present conditions with a detail plan of remedial action of the pollution problems is needed. Since Towns do not have the finances to correct abandoned dump pollution sources, or existing sites, a Federal-State program is needed for the preservation of the regions present and future surface and groundwater supplies.

The recycling of metals and papers can have a large effect on solid waste disposal both with the amount of land required and the potential pollution problems that would be eliminated.

H. EXISTING WATER QUALITY IN SELECTED STREAMS

In order to determine the quality of the waters of the Merrimack River Basin, a sampling and analysis program was developed covering some 164 sampling locations throughout the basin.

Sampling locations were chosen at existing public waste treatment plant outfalls, at points below suspected sewage discharge sources, at point sources from solid waste disposal sites, in streams below subdivision and apartment complexes known to have on-lot waste disposal systems, along the entire length of the Merrimack River, along sections of the Assabet and Concord Rivers, and in streams which feed public water supplies. The geographical location of these stations are listed in Table 9 and are shown on the basin map at the end of this report.

Monthly grab samples were collected using standard sampling procedures with bacteriological and chemical analysis conducted by the United States Environmental Protection Agency Laboratories. The bacteriological samples were analyzed at the National Marine Laboratory in West Kingston, Rhode Island while the chemical analysis were done at the EPA laboratory in Cincinnati, Ohio. Refrigerated bacteriological samples were delivered to Rhode Island either by automobile or by U.S. Army helicopter. Preserved chemical samples were sent to Ohio by regular mail until April after which they were delivered by U.S. Air Force cargo planes. The sampling period extended from August 1973 through May 1974.

A set of natural background water quality data was collected on thirteen small water supply feeder streams located within the Nashua River Basin. The results of this sampling are given on Table 10. The streams sampled are located in the sparsely populated towns of Holden, Rutland, Princeton, Sterling, Northboro, Townsend, Leominster, and Boylston. The land has some agricultural activities such as dairy farming, hog raising and fruit orchards. A large percentage of the area is natural forested land inhabited by deer, foxes, rodents, birds, and other native wildlife of the region.

The water quality of these streams is excellent as can be seen from the data on Table 10. Bacteriological counts are very low, with the majority of the stations showing less than 10 fecal coliform counts per 100 ml. The chloride concentrations are less than 10 mg/l and the nitrate concentration less than 1 mg/l at most of the stations. Where runoff from agricultural activities influenced the quality of the streams, for example, hog farming near Station 64A, Alpha Brook, the nitrate concentrations increase slightly. Turbidities of less than 1 TU indicate the filtering action of forest cover and minimal soil erosion. The pH is generally between 5.0 to 6.8. This corresponds to slightly acidic water which is characteristic of uninhabited forested areas.

With the natural background quality as a guide for undeveloped areas, samples were collected at 128 stations throughout the

TABLE 9
Merrimack River Basin Study
Water Quality Sampling Stations
Showing
Massachusetts Coordinate Location and Graphical Location

Group	Station	Town	Quadrangle	Stream or Watershed Name	Coordinate North	Coordinate East	Longitude	Latitude
STP	1	Ashburnham	Ashburnham	Phillips Brook	595,550	489,550	71-54-37.53	42-38-0.91
1	1a	Ashburnham	Ashburnham	Phillips Brook	596,305	488,390	71-54-53.10	42-38-8.31
2	2	Ashby	Ashby	Forbes	608,300	516,680	71-48-35.23	42-40-7.98
D	2a	Ashby	Ashby	Locke Brook Trib-Dump	614,350	524,150	71-46-55.50	42-41-7.99
D	3	Ayer	Ayer	Town Dump Outfall	571,000	580,800	71-34-16.57	42-34-0.95
3	4	Ayer	Ayer	Nonacoicus Brook	569,040	570,200	71-36-38.19	42-33-41.47
3	5	Groton	Ayer	James Brook	582,500	581,300	71-34-10.01	42-35-54.55
3	6	Groton	Ayer	Wrangling Brook	584,700	570,500	71-36-34.45	42-36-16.17
3	7	Haverhill	Salem Depot	Bare Meadow Brook	642,150	698,850	71-7-54.95	42-45-41.73
3	7a	Haverhill	Salem Depot	Crystal Lake Tributary	660,550	694,050	71-8-58.28	42-48-43.67
3	8	Billerica	Billerica	Webb Brook	562,800	666,620	71-15-10.06	42-32-39.07
D	9	Billerica	Billerica	Canal - East	577,700	665,850	71-15-19.78	42-35-6.27
D	10	Billerica	Billerica	Canal - West	577,600	665,400	71-15-52.53	42-35-5.36
3	10a	Billerica	Billerica	Concord River	576,150	657,200	71-17-15.46	42-34-15.19
3	10b	Bedford	Billerica	Concord River	549,650	649,650	71-18-57.13	42-30-29.59
2	11	Chelmsford	Billerica	River Meadow Brook	585,800	645,050	71-19-57.60	42-36-26.78
2	11a	Chelmsford	Billerica	Black Brook	590,650	640,250	71-21-1.67	42-37-14.78
2	11b	Chelmsford	Billerica	River Meadow Brook	582,900	643,250	71-20-21.74	42-35-58.17
2	11c	Chelmsford	Billerica	River Meadow Brook	580,000	642,750	71-20-28.50	42-35-29.54
2	11d	Chelmsford	Billerica	Putnam Brook	579,000	640,450	71-20-59.27	42-35-19.70
2	11e	Chelmsford	Billerica	Farley Brook	575,000	640,100	71-21-4.04	42-34-40.19
2	11f	Chelmsford	Billerica	Beaver Brook	581,690	639,700	71-21-9.24	42-35-46.28
2	11g	Chelmsford	Westford	Pond Brook	570,500	631,690	71-22-56.53	42-33-55.87
2	11h	Chelmsford	Westford	Beaver Brook	578,750	626,850	71-24-1.08	42-35-17.43
3	12	Lancaster	Clinton	North Nashua Tributary	527,650	548,700	71-41-24.24	42-26-52.23
STP	12a	Clinton	Clinton	MDC Treatment Plant	521,350	551,550	71-40-46.05	42-25-50.06
3	13	Sterling	Clinton	Wekepeke Brook	533,850	535,100	71-44-25.87	42-27-53.14
3	13a	Lincoln	Concord	Sudbury River	636,600	517,100	71-48-30.97	42-44-47.54
3	13b	Concord	Concord	Concord River	640,400	536,050	71-44-17.16	42-45-25.67
STP	13c	Concord	Concord	Sewage Disposal@Concord R	643,550	537,600	71-43-56.50	42-45-56.83
1	14	Fitchburg	Fitchburg	Sawmill Pond Brook	564,950	506,150	71-50-53.80	42-32-59.37
1	14a	Westminster	Fitchburg	Sawmill Pond Brook	561,900	502,550	71-52-8.43	42-32-29.01
STP	15	Marlboro East	Framingham	Hager Pond Brook	492,150	602,400	71-29-28.04	42-21-2.11
1	15a	Framingham	Framingham	Sudbury River	481,700	627,350	71-23-55.93	42-19-18.71

Group Key -
STP - Sewage Treatment Plant
D - Dump

1 - Recreational streams
2 - Water supply streams
3 - Other feeder streams

Massachusetts Coordinate Location and Graphical Location (Cont'd)

Group	Station	Town	Quadrangle	Stream or Watershed Name	Coordinate North	Coordinate East	Longitude	Latitude
1	16	Ashburnham	Gardner	Whitman River	586,700	485,350	71-55-33.12	42-36-33.28
1	16a	Ashburnham	Gardner	Whitman River	586,500	482,650	71-56-9.21	42-37-0.81
1	17	Westminster	Gardner	Round Meadow Pond	562,750	492,650	71-53-54.01	42-32-37.05
1	17a	Westminster	Gardner	Round Meadow Pond Brook	564,650	496,350	71-53-4.70	42-32-55.99
1	17b	Westminster	Gardner	Round Meadow Pond Trib	564,300	489.700	71-54-33.52	42-32-52.23
1	18	Boxford	Georgetown	Fish Brook	576,150	741,200	70-58-52.71	42-34-47.61
1	19	Georgetown	Georgetown	Pentucket Pond Brook	631,300	736,800	70-59-27.13	42-43-52.63
3	20	Haverhill	Haverhill	East Meadow River	660,400	725,350	71-1-58.40	42-48-40.71
3	21	Groveland	Haverhill	Johnson Creek	639,650	722,750	71-2-34.77	42-45-15.90
1	21a	Groveland	Haverhill	Merrimack River	643,150	724,700	71-2-8.37	42-45-50.36
1	22	Holliston	Holliston	Winthrop Canal	437,250	619,700	71-25-38.27	42-11-59.67
2	23	Hudson	Hudson	Crystal Spring	506,550	575,125	71-35-31.48	42-23-24.23
D	23a	Hudson	Hudson	Hudson Dump	506,550	576,600	71-35-11.82	42-23-24.24
1	24	Bolton	Hudson	Sunken Meadow Brook	522,200	570,750	71-36-30.04	42-25-58.78
D	25	Harvard	Hudson	Elizabeth Brook	536,850	583,700	71-33-37.50	42-28-23.62
1	25a	Boxboro	Hudson	Beaver Brook	544,800	588,650	71-32-31.49	42-29-42.18
1	26	Hudson	Hudson	Assabet River Tributary	509,950	586,700	71-32-57.26	42-23-57.91
1	27	Stow	Hudson	Assabet River	511,800	592,850	71-31-35.30	42-24-16.21
2	28	Andover	Lawrence	Fish Brook	608,300	681,800	71-11-45.12	42-40-8.04
D	28a	Andover	Lawrence	Andover Dump	608,900	683,250	71-11-25.68	42-40-13.91
3	29	Andover	Lawrence	Shawsheen River	600,450	693,800	71-9-4.93	42-38-50.04
1	30	Lawrence	Lawrence	Merrimack River	620,000	694,350	71-8-56.50	42-42-3.13
1	30a	Lawrence	Lawrence	Spicket River	622,350	689,350	71-10-3.33	42-42-26.54
1	30b	Lawrence	Lawrence	Lawrence Canal	622,450	694,350	71-8-56.36	42-42-27.33
1	30c	Lawrence	Lawrence	Lawrence Canal	620,550	693,700	71-9-5.17	42-42-8.59
1	30d	Methuen	Lawrence	Merrimack River	620,125	677,900	71-12-36.78	42-42-4.97
1	31	Methuen	Lawrence	Spicket River	630,250	678,250	71-12-31.63	42-43-44.97
3	31a	Methuen	Lawrence	Harris Brook	635,350	668,450	71-14-42.72	42-44-35.66
1	32	Dracut	Lowell	Beaver Brook	609,300	641,390	71-20-45.97	42-40-18.99
STP	32a	Lowell	Lowell	Merrimack River	600,450	645,250	71-19-54.54	42-38-51.49
1	32b	Lowell	Lowell	Lowell Canal	601,750	649,900	71-18-52.48	42-39-4.24
1	32c	Lowell	Lowell	Lowell Canal	600,600	651,100	71-18-36.26	42-38-52.85
1	32d	Lowell	Lowell	Merrimack River	600,500	652,150	71-18-22.22	42-38-51.84
1	32e	Lowell	Lowell	Concord River	598,375	652,825	71-18-13.25	42-38-30.84
2	33	Lowell	Lowell	Black Brook	595,150	640,000	71-21-4.91	42-37-59.24
2	34	Lowell	Lowell	Black Brook	593,200	640,900	71-20-52.92	42-37-39.96

Massachusetts Coordinate Location and Graphical Location (Cont'd)

Group	Station	Town	Quadrangle	Stream or Watershed Name	Coordinate North	Coordinate East	Longitude	Latitude
STP	35	Marlboro	Marlboro	Assabet River	489,800	568,900	71-36-54.13	42-20-38.68
1	36	Westboro	Marlboro	Chauncey Lake	472,900	568,700	71-36-56.49	42-17-51-73
1	36a	Westboro	Marlboro	Chauncey Lake	469,550	569,250	71-36-49.11	42-17-15.64
2	37	Southboro	Marlboro	Sewage Treatment Outfall	479,300	592,400	71-31-41.16	42-18-55.15
1	38	Acton	Maynard	Fort Pond Brook	531,400	610,750	71-27-36.59	42-27-29.82
1	39	Acton	Maynard	Waste Disposal	529,050	619,850	71-25-35.22	42-27-6.54
1	39a	Concord	Maynard	Assabet River	525,550	619,750	71-25-36.60	42-26-31.97
1	40	Concord	Maynard	Assabet River	530,600	629,450	71-23-27.14	42-27-21.75
STP	40a	Concord	Maynard	Assabet River	533,550	628,800	71-23-35.77	42-27-50.90
1	41	Concord	Maynard	Second Division Brook	525,350	624,300	71-24-35.92	42-26-29.95
D	42	Maynard	Maynard	Second Division Brook	521,200	617,350	71-26-8.65	42-25-49.02
1	43	Chelmsford	Nashua South	Stony Brook	597,050	633,400	71-22-33.16	42-38-18.11
1	43a	Chelmsford	Nashua South	Deep Brook	598,550	630,000	71-23-18.62	42-38-32.97
1	44	Tyngsboro	Nashua South	Mascuppic Lake Tributary	612,400	630,750	71-23-8.34	42-40-49.77
2	44a	Tyngsboro	Nashua South	Merrimack River	610,850	621,350	71-25-14.20	42-40-34.57
1	45	Tyngsboro	Nashua South	Mascuppic Lake	613,350	631,950	71-22-52.26	42-40-59.14
STP	46	Newburyport	Newburyport East	Merrimack Sewer Outlet	660,000	771,400	70-51-40.69	42-48-33.81
1	46a	Newburyport	Newburyport East	Merrimack River	662,650	768,500	70-52-19.33	42-49-0.19
D	47	Salisbury	Newburyport East	Salisbury Dump-Black Rock	672,850	779,000	70-49-57.39	42-50-40.16
1	48	Amesbury	Newburyport West	Powwow River	671,550	754,100	70-55-31.71	42-50-29.11
1	49	Merrimac	Newburyport West	Cobbler Brook	665,800	738,350	70-59-3.57	42-49-33.31
STP	50	Paxton	Paxton	Sew Treatm Anna Maria	486,000	484,750	71-55-34.42	42-19-58.51
2	50a	Paxton	Paxton	Kettle Brook Res Trib	474,350	489,100	71-54-35.76	42-18-3.63
1	51	Pepperell	Pepperell	Nissitissit River	609,150	579,200	71-34-38.42	42-40-17.78
3	52	Pepperell	Pepperell	Reedy Meadow Brook	607,600	582,550	71-33-53.56	42-40-2.50
3	53	Leominster	Shirley	Fall Brook	550,800	535,725	71-44-18.16	42-30-40.60
D	54	Leominster	Shirley	No. Nashua River @ Dump	554,450	536,300	71-44-10.62	42-31-16.67
1	55a	Lunenberg	Shirley	Hickory Hills Lake	585,250	545,300	71-42-11.42	42-36-21.14
3	55b	Lunenberg	Shirley	Catacoonamug Br Swamp	579,600	536,650	71-44-6.87	42-35-25.11
3	56	Shirley	Shirley	Catacoonamug Brook	562,550	557,575	71-39-26.72	42-32-37.17
3	57	Shirley	Shirley	Catacoonamug Brook	561,750	562,750	71-38-17.58	42-32-29.35
STP	58	Shirley	Shirley	Nashua River	556,250	562,700	71-38-18.13	42-31-35.02
STP	59	Boylston	Shrewsbury	Pump Sta Mt Pleas c.c.	493,100	542,050	71-42-51.78	42-21-10.78
1	60	Northboro	Shrewsbury	Hop Brook	471,250	555,700	71-39-49.43	42-17-35.02
3	61	Shrewsbury	Shrewsbury	Rawson Hill Brook	480,500	544,900	71-42-13.42	42-19-6.37
3	61a	Shrewsbury	Shrewsbury	Rawson Hill Brook	481,000	541,700	71-42-56.03	42-19-11.23
STP	62	Northboro	Shrewsbury	Assabet River	470,000	561,300	71-38-34.89	42-17-22.97
STP	63	Westboro	Shrewsbury	Assabet River	466,100	562,450	71-38-19.51	42-16-44.46
2	64	Sterling	Sterling	Waushacum Pond Trib	520,750	527,850	71-46-2.05	42-25-43.52
B	64a	West Boylston	Sterling	Quinapaxet River Trib	507,350	516,600	71-48-31.41	42-23-30.77

Massachusetts Coordinate Location and Graphical Location (Cont'd)

Group	Station	Town	Quadrangle	Stream or Watershed Name	Coordinate North	Coordinate East	Longitude	Latitude
2	65	Groveland	South Groveland	Johnson Brook	635,200	724,050	71-2-17.67	42-44-31.87
2	65a	North Andover	South Groveland	Lake Cochewick Trib	619,350	713,000	71-4-46.79	42-41-55.86
2	65b	North Andover	South Groveland	Lake Cochewick Trib	614,650	706,700	71-6-11.44	42-41-9.75
2	65c	North Andover	South Groveland	Lake Cochewick Trib	617,200	709,800	71-5-29.77	42-41-34.79
3	66	Townsend	Townsend	Squannacook River Trib	612,450	546,350	71-41-58.23	42-40-49.85
3	66a	Townsend	Townsend	Squannacook River	611,550	539,600	71-43-28.56	42-40-40.79
D	66b	Townsend	Townsend	Squannacook River Trib	612,450	540,450	71-43-17.21	42-40-49.70
2	67	Acton	Westford	Nagog Brook Trib	548,050	620,800	71-25-22.32	42-30-14.23
2	67a	Acton	Westford	Nagog Pond	553,850	618,000	71-25-59.64	42-31-11.54
2	67b	Acton	Westford	Nagog Brook Trib	557,700	618,550	71-25-52.32	42-30-50.30
2	67c	Acton	Westford	Nagog Brook Trib	549,450	621,000	71-25-19.64	42-30-28.05
2	67d	Acton	Westford	Nonset Brook Trib	556,750	619,550	71-25-38.91	42-31-40.18
2	67e	Acton	Westford	Nonset Brook Trib	551,375	619,650	71-25-37.57	42-31-46.35
2	68	Acton	Westford	Nashoba Brook	548,700	623,200	71-24-50.27	42-30-20.62
2	69	Westford	Westford	Stony Brook	577,350	605,550	71-28-45.81	42-35-3.74
2	70	Westford	Westford	Boutwell Brook	580,400	608,950	71-28-0.35	42-35-33.86
3	71	Billerica	Wilmington	Webb Brook	562,000	670,250	71-14-21.60	42-32-31.06
3	72	Tewksbury	Wilmington	Shawsheen River Trib	583,700	683,800	71-11-19.55	42-36-4.97
3	72a	Tewksbury	Wilmington	Shawsheen River Trib	582,200	684,850	71-11-5.59	42-35-50.11
3	73	Tewksbury	Wilmington	Strong Water Brook	581,750	681,700	71-11-47.72	42-35-45.78
2	74	Wilmington	Wilmington	Maple Meadow Brook	560,400	691,250	71-9-41.18	42-32-14.53
3	75	Wilmington	Wilmington	Lubber Brook	572,250	691,850	71-9-32.53	42-34-11.56
2	76	Holden	Worcester North	Chaffin Pond Trib	471,150	505,650	71-50-55.35	42-17-32.75
2	77	Holden	Worcester North	Poor Farm Brook	471,600	509,200	71-50-8.14	42-17-37.33
2	78	Shrewsbury	Worcester North	Lake Quinsigamond	464,500	531,000	71-45-17.80	42-16-27.94
2	79	West Boylston	Worcester North	Scarlett's Brook	485,000	524,450	71-46-45.82	42-19-50.25
2	79a	West Boylston	Worcester North	Gates Brook	476,900	518,650	71-48-3.32	42-18-30.04
2	79b	West Boylston	Worcester North	Gates Brook	483,750	523,800	71-46-54.42	42-19-37.39
2	80	West Boylston	Worcester North	Scarlett's Brook Trip	485,950	523,450	71-46-59.18	42-19-59.60
2	81	Rowley	Georgetown	Ox Pasture Brook	627,350	767,250	70-52-39.55	42-43-11.62
1	82	Dracut	Lowell	Long Pond	617,250	635,325	71-22-6.99	42-41-37.61
2	83	Tyngsboro	Nashua South	Long Pond Trib	616,350	633,400	71-22-32.79	42-41-28.75
2	84	Southboro	Marlboro	Sudbury River Trib	463,700	594,600	71-31-11.83	42-16-11.17
1	85	Groveland	South Groveland	Johnson's Pond Trib	631,600	718,450	71-3-32.96	42-43-56.60
2	86	West Boylston	Worcester North	Gates Brook Trib	478,250	516,300	71-48-34.0	42-18-43.29
2	87	Holden	Worcester North	Chaffin Pond Trib	477,550	511,000	71-49-44.50	42-18-36.18
B	88	Holden	Wachuset Mt	Muschopauge Pond Brook	601,650	488,700	71-54-49.30	42-39-1.12
B	89	Rutland	Wachusett Mt	Muschopauge Brook	509,600	486,600	71-55-11.33	42-32-51.73
B	90	Princeton	Sterling	Governor Brook	522,500	504,500	71-51-13.49	42-25-59.97

Massachusetts Coordinate Location and Graphical Location (Cont'd)

Group	Station	Town	Quadrangle	Stream or Watershed Name	Coordinate North	Coordinate East	Longitude	Latitude
B	91	Holden	Wachusett Mt	Quinapaxet Res	504,850	495,050	71-53-18.43	42-23-5.21
2	91a	Holden	Paxton	Asnebumskit Brook	497,750	496,600	71-52-57.35	42-21-55.14
2	91b	Holden	Worcester North	Tannery Brook	495,000	500,700	71-52-2.58	42-21-28.15
2	91c	Holden	Paxton	Asnebumskit Brook	497,450	496,550	71-52-58.00	42-21-52.17
2	91d	Holden	Paxton	Asnebumskit Brook	496,200	496,000	71-53-5.25	42-21-39.80
B	92	Sterling	Sterling	Scanlon Brook	518,100	516,750	71-48-29.93	42-25-16.97
B	93	Holden	Sterling	Trout Brook	504,350	508,800	71-50-15.19	42-23-0.84
B	94	Sterling	Sterling	Ball Brook	523,350	514,100	71-49-5.52	42-26-8.74
B	95	Sterling	Sterling	Gamma Brook	533,900	512,275	71-49-30.30	42-27-52.89
B	96	Leominster	Fitchburg	Haynes Res Outlet	553,275	519,100	71-48-0.24	42-31-4.53
B	97	Townsend	Townsend	Beta Brook	612,500	544,000	71-42-26.69	42-40-50.29
B	98	Northboro	Shrewsbury	Howard Brook	489,150	555,750	71-39-49.22	42-20-32.05
B	99	Boylston	Clinton	Wrack Meadow Brook	552,950	502,650	71-51-39.88	42-31-0.69
2	100	Holden	Paxton	Maple Spring Pond Brook	499,150	490,550	71-54-18.03	42-22-8.69

TABLE 10
1974
WATER QUALITY OF STREAMS
FROM SPARCELY POPULATED WATERSHEDS (BASELINE DATA)

Town and Stream	Station	Jan	Feb	Mar	Apr	May	Feb	Mar	Apr	May	Feb	Mar	Apr	May	Feb	Mar	Apr	May
		Fecal Coliform/Total Coliform					Turbidity				Chloride				Nitrate			
W. Boylston Alfa Brook	64A	1/28	4/22	1/1	0/1	60/39	.38	.58	.60		<10	<10	<10		4	3	<2	
Holden Maynard Brook	88	2/37		3/61	7/6	22/86	-	.23	.22			14	<12			<1	<1	
Rutland Muschopauge	89		1/2	0/35	2/2	18/24	.22	.30	.32		<10	<10	<10		<1	<1	<1	
Princeton Governor	90		0/0	0/26	0/0	76/330	.23	.22	.37		<10	<10	<10		<1	<1	<1	
Whitney Street Maynard Brook	91		6/21	4/84	7/9	9/35	.23	.24	.60		13	12	12		<1	<1	<1	
Sterling Scanlon Brook	92		1/0	0/0	0/0	2/111	.40	-	.45		<10	-	<10		2	-	2	
Holden Ball Brook	93		0/12	3/118	13/1	9/34	.32	.40	.40		<10	<10	<10		<1	<1	<1	
Sterling Ball Brook	94		0/0	0/132	0/0	2/9	.30	.40	.37		<10	<10	<10		<1	<1	<1	
Sterling Gamma Brook	95		0/0	0/14	0/0	18/24	.15	.23	.25		<10	<10	<10		<1	<1	<1	
Leominster Haynes Brook	96		1/20				.28	.25	-		<10	-	-		<1	-	-	
Townsend Beta Brook	97		0/2				.32	-	-		10	-	-		<1	-	-	
Northboro Howard Brook	98		21/25				.25	-	-		<10	-	-		2	-	-	
Boylston Wrack Meadow	99		0/18				.30	-	-		10	-	-		<1	-	-	

1974 Baseline Data (Cont'd)

Town and Stream	Feb	Mar	Apr	May	Feb	Mar	Apr	May	Feb	Mar	Apr	May	Watershed Area square mile
	Specific Conductance				pH				Lead				
W. Boylston Alfa Brook	68	65	63		6.2	7.0	6.8		0	0	0		.88
Holden Maynard Brook		75	74			6.5	6.6		–	0	0		.84
Rutland Muschopauge	44	43	42		5.2	5.5	5.8		0	0	0		2.0
Princeton Governor	40	38	38		5.0	5.2	5.9		0	0	0		.81
Whitney Street Maynard Brook	80	78	79		6.2	6.8	6.8		0	0	0		1.31
Sterling Scanlon Brook	39	–	38		5.5	–	6.0		0	–	0		.90
Holden Ball Brook	42	38	40		4.8	5.5	5.0		0	0	0		6.70
Sterling Ball Brook	30	28	30		5.2	5.7	5.9		0	0	0		.44
Sterling Gamma Brook	38	37	38		5.2	5.5	5.6		0	0	0		.62
Leominster Haynes Brook	32	–	–		4.5	–	–		0	–	–		.74
Townsend Beta Brook	33	–	–		4.8	–	–		0	–	–		1.17
Northboro Howard Brook	73	–	–		6.1	–	–		0	–	–		.75
Boylston Wrack Meadow	40	–	–		4.4	–	–		0	–	–		1.40
												Total	19.56

Merrimack River Basin. The effects of development on water quality can be seen. The streams sampled were grouped into three categories:

1. Recreational

Those streams used for fishing, swimming, and other contact sports, streams that flow into rivers, ponds, and lakes that are used for recreational purposes, or streams with potential for recreational use. Table 11.

2. Water Supply

Those streams that are sources or potential sources of surface or subsurface water supplies. Table 12.

3. Other Feeder Streams

Those streams which presently do not have any direct recreational or water supply importance. Table 13.

To evaluate the water quality at each sampling station, the data was compared to a set of established standards, which are dependent on the assigned water usage for that particular group of streams.

The proposed EPA criteria for bacteriological water quality of recreational waters are: (35)

Primary recreational (contact)-log mean of 200 fecal coliforms/100 ml and not more than 10% of the total samples to exceed 400 fecal coliform/100 ml in any 30 day period. A minimum of 5 samples are to be taken in any 30 day period of the recreation season.

Secondary Recreational (non-contact)-average of 2,000 fecal coliforms/100 ml, maximum of 4,000 fecal coliforms/100 ml.

The recreational streams sampled varied in water quality. Applying the above criteria to the date on Table A, Stations 14, 14a, 15a, 16, 19, 25a, 26, 36a, 38, 41, 44, 46a, 55a, 60, and 82 meet primary contact recreational criteria; stations 1a, 17a, 18, 27, 30a, 30b, 30c, 31, 32, 32b, 32c, 32d, 32e, 39a, 40, 43a, and 48 meet secondary, non-contact recreational criteria; stations 17, 17b, 21a, 24, 30, 30d, 43, 45, 49, and 51 do not meet the secondary non-contact recreational criteria.

The proposed EPA bacterial water quality criteria for raw water used as a public water supply after disinfection only is: (35)

fecal coliform not to exceed 20 per 100 ml on a monthly arithmetic mean;

total coliform not to exceed 100 per 100 ml on a monthly arithmetic mean.

Table 11
Merrimack River Basin
Water Quality Data 1973-1974
Group I - Recreational Waters

Station	Water Source	Total Coliform Aug	Sept	Nov	Jan	Mar	Apr	May	Fecal Coliform Aug	Sept	Nov	Dec	Jan	Mar	Apr	May	Chlorides Aug	Sept	Nov	Jan	Mar	Apr	May
1a	Phillips Brook					800	310	110						10	410	47					65	54	55
14	Sawmill Brook	500	200	290													10	10	15				
14a	Sawmill Brook			260		24	470	47			4			0	7	7			10		<10	<10	10
15a	Sudbury River			900							110	125							42				
16	Whitman River	2100	1300	58,000				800	220	26	360					110	<10	<10	10				<10
16a	Whitman River																						
17	Round Meadow Pond	200	2300	29,000		1000	63,000	1300	200	370	5100			70	430	380	84		54		130	70	110
17a	Round Meadow Pond Br		5500	520		47	2600	250		1010	116			17	60	110		39	37		43	43	30
17b	Round M Pond Trib			17,000		850,000	8900	5200			300			54000	440	410			33		22	26	15
18	Fish Brook	900	900	710					700	170	104						25	17	19				
19	Pentucket Pond Brook	10	40	21					0	10	0						15	12	15				
21a	Merrimack River			76000				1,600,000			4800					1,900,000			20			40	
22	Winthrop Canal																						
24	Bolton Center Brook	400	27,000	65,000	2500	700	13,800	3300	200	79	9900		190	730	130	650	<10	11	11	27	24	18	<10
25a	Elizabeth Brook									54			0		400	300		390		40		44	25
26	Assabet River Trib			6300							800								34				
27	Assabet River	69,000	4400	6400					1120	720	130						25	40	26				
30	Spicket River	90,000	70,000	310,000				200,000	800	18,000	30,900					710	23	43	22			80	
30a	Merrimack River		300	5400						130	1000								16			15	
31	Spicket River	200	1100	26,000					200	139	2700						23	30	35				
32	Beaver Brook	16,000	46,000	14,000		1000	0	160	560	1970	5100			1000	0	0	23	40	30		17	18	70
36	Chauncey Lake			700							90								11				
36a	Stream@ S end of Chauncey		8400	100		150	67	250		17	10	25		1	34	3		42	39		28	27	15
38	Fort Pond Brook	16	540	2000					6	34	230						27	37	32				
39a	Assabet River			2700							540								33				
40	Assabet River	550	6800	18,000		1550	2300	11,000	530	580	3000			147	530	1480	21	33	28		22	23	25
41	Second Div Brook		11200	120						12	32							23	24				
43	Stony Brook	14000	820000	32000				160,000	1200	42,300	2900	3500				3600	40	40	42				35
43a	Deep Brook			9000		8400	4600	1400				68		410	430	360			42		45	50	40
44	Brook @Chicken Plant		600	590		42	54	420		300	230			7	4	16		45	22		20	20	20
45	Mascuppic Lake	39,000	270,000	27,000		100	3500	3000	1350	1120	1800			600	1000	1400	75		56		70	88	75
46a	Merrimack River			1700				50			330					10			13,200			75	
48	Powwaw River	12,000	13,000	15,000		8400	5100	0	500	1680	830			760	1800	0	100	2400	54		11	14	20
49	Cobbler Brook	58,000	114,000	110,000		500,000	330,000	45,000	700	14,800	17,000			630,000	130,000	900			50		46	27	20
51	Nissitissit River	1000	45,000	340		40	220	42	158	5500	110			1	59	29	12	<10	11		<10	<10	<10

Table 11 (Cont.)

		Total Coliform							Fecal Coliform								Chlorides						
Station	Water Source	Aug	Sept.	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Dec	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
55a	Hickory Hills Lake		14	14						0								15	16				
60	Hop Brook	24000	16,000	2400		260	110	390	116	79	0	202		3	159	10	40	29	36		17	31	15
82	Long Pond					2400	58							124	0						90	88	
85	Johns. Pond Trib																						
30b	North Canal					3300	3500	5000						370	490	800					< 10	11	16
30c	South Canal					670	6700	1200						69	2600	0					10	11	
30d	Merrimack River					3300	8400							530	6200						10	15	
32b	Tremont Canal					5500	6200	3900						200	700	250					11	< 10	15
32c	Merrimack Canal					1300	1700	2000						100	260	70					12	< 10	10
32d	Merrimack River Canal						590,000								3000							15	
32e	Lower Locks Dam					1400	4000	1300						200	1600	1400					26	35	40

Table 11 (Cont.)

Station	Water Source	Phosphorous							Specific Conductance							Color						
		Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
1a	Phillips Brook					.01	.03	.02					263	247	226					3	0	0
14	Sawmill Brook	.03	2.75	<.01					70	62	115						8	20				
14a	Sawmill Brook			<.01		.08		.02			56		52	53	52			12		7	3	3
15a	Sudbury River										248							26				
16	Whitman River	.03	.05	.02					81	35	106				40	50+	35	15				3
16a	Whitman River																					
17	Round Meadow Pond	.02				.03		.01	1080	1195	280		500	316	436	13	13	28		2	10	3
17a	Round M Pond Brook		.05	<.01		.03		.04		200	198		181	131	150		25	40		13	15	25
17b	Round M Pond Trib			<.01		.01	.04	.04			154		110	122	90			50		30	40	50
18	Fish Brook	.01	<.01	.05					164	160	155					50+	38	>50				
19	Pentucket Pond Brook	.01	<.01	.06					116	127	146					48	40	32				
21a	Merrimack River			.11							145			374				12			45	
22	Winthrop Canal																					
24	Bolton Center Brook	.03	.23	.11	.05	.04		<.01	106	142	140	198	147	146	65	13	25	5	3	3	0	3
25a	Elizabeth Brook									1680		333		284	280		15		>50		8	>50
26	Assabet River Trib			.35							208											
27	Assabet River			.41					202	290	212					>50	38	30				
30	Spicket River	.19	.39	.20					180	252	175			432							5	
30a	Merrimack River			.08							150			75							7	
30b	North Canal												66	238	73					13	10	5
30c	South Canal						.05	.02					65	73						13		
30d	Merrimack River					.06	.05						68	94						12	27	
31	Spicket River	.29	.29	.13					147	185	218											
32	Beaver Brook	.03	.05	.06		.07	.19	2.1	170	230	210		102	252	374			28		32	3	3
32b	Tremont Canal					.09	.02	.01					74	67	70					8	13	3
32c	Merrimack Canal					.36	.05	.2					76	64	66					13	13	10
32d	Merrimack River Canal						.06							94							5	
32e	Lower Locks Dam					.06	.07	.07					142	188	192					17	13	13
36	Chauncey Lake			.10							192							>50				
36a	Stream@S end Chauncey		.03	.03		.02	.08	.02		305	260		195	165	157		26	20		13	13	13
38	Fort Pond Brook	.04	.01	.02					210	244	198					50	55	>50				
39a	Assabet River			.62							242							22				
40	Assabet River	.39	.29	.38		.15	.11		192	247	220		136	140	146	50		30		13	13	15
41	Second Div Brook		<.01	<.01						192	170						35	42				
43	Stony Brook	.02	.42	.10				.02	252	264	283				174		42	28				13
43a	Deep Brook			.05		.01	<.01	.01			234		220	234	171			50		27	17	30
44	Brook @ Chicken Plant		.08	.02			.02	.02		210	150		110	111	107		>50	30		13	23	10

Table 11 (Cont.)

		Phosphorous							Specific Conductance							Color						
Station	Water Source	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
45	Mascuppic Lake	.02		.11		<.01	.04	.1	283		283		290	413	346	13		8		12	7	2
46a	Merrimack River										38310			322				3			12	
48	Powwow River	.09	.10	.09		.08	.04	.02	485	7665	350		75	87	101					12	13	35
49	Cobbler Brook			.23		1.17	.37	.69			350		276	166	146			>50		22	3	3
51	Nissitissit River	<.01	<.01	<.01		.01	.02	.01	84	120	136		55	66	46					13	13	13
55a	Hickory Hills Lake		.04	.03						105	114						3	4				
60	Hop Brook	.03	.02	.33		.09	<.01	.02	179	190	185		123	177	140		56	47		13	14	25
82	Long Pond					.01	.02						405	407						7	12	
85	Johnson Pond Trib																					

Table 11 (Cont.)

Station	Water Source	pH							Nitrates						
		Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
1a	Phillips Brook					6.3	6.7	7.6					4	2	2
14	Sawmill Brook		6.5	6.4					< 1	< 1	1				
14a	Sawmill Brook			6.4		6.2	6.4	6.6			< 1		< 1	2	< 1
15a	Sudbury River			6.7							1				
16	Whitman River	6.2	5.6	6.2				5.4	1	<1	2				< 1
16a	Whitman River														
17	Round Meadow Pond	7.1	6.8	6.4		6.6	6.5	6.6	6	8	2		3	1	2
17a	Round M Pond Brook		6.4	6.2		6.3	6.1	6.1		1	1		1	1	< 1
17b	Round M Pond Trib			6.2		6.4	6.0	5.9			1		1	1	
18	Fish Brook	7.1	7.0	6.6					1	< 1	< 1				
19	Pentucket Pond Brook	7.0	6.8	7.0					< 1	<1	<1				
21a	Merrimack River			6.5			6.4				2			8	
22	Winthrop Canal														
24	Bolton Center Brook	6.8	6.3	6.5	6.4	6.6	6.6	6.6	1	3	3	10	5	4	< 1
25a	Elizabeth Brook		6.8	6.6			6.3	6.6		1		9		3	2
26	Assabet River Trib										3				
27	Assabet River	6.8	6.6	6.5					2	5	3				
30	Spicket River						7.0		3	5	3			5	
30a	Merrimack River						6.3				2			2	
30b	North Canal					6.5	6.5	6.4					1	1	<1
30c	South Canal					6.0							1	2	
30d	Merrimack River					6.3	7.1						1	2	
31	Spicket River								1	2	3				
32	Beaver Brook			6.6		6.3	7.6	7.0	1	1	2		1	3	2
32b	Tremont Canal					6.2	7.0	6.3					1	1	1
32c	Merrimack Canal					6.3	6.5	6.2					1	1	1
32d	Merrimack R Canal						6.6							2	
32e	Lower Locks Dam					6.6	6.8	6.9					2	3	1
36	Chauncey Lake			6.9							<1				
36a	Stream@S end of Chauncey		6.7	6.8		7.0	7.0	7.1		< 1	2		4	1	< 1
38	Fort Pond Brook	6.8	6.6	6.4					2	2	1				
39a	Assabet River			6.8							5				
40	Assabet River	7.0		6.6		6.3	6.7	6.6	3	3	4		2	2	2
41	Second Div Brook		6.8	6.8						1	2				
43	Stony Brook		6.8	6.5				6.8	1	2	3				1
43a	Deep Brook			6.6		6.4	7.2	6.8			<1		1	<1	<1
44	Brook@Chicken Plant		6.4	6.5		6.6	6.8	7.2		< 1	< 1		1	1	<1

Table 11 (Cont.)

Station	Water Source	pH Aug	pH Sept	pH Nov	pH Jan	pH Mar	pH Apr	pH May	Nitrates Aug	Nitrates Sept	Nitrates Nov	Nitrates Jan	Nitrates Mar	Nitrates Apr	Nitrates May
45	Mascuppic Lake	7.6		6.2		6.8	6.8	7.0	<1		2		1	<1	3
46a	Merrimack River			7.4			6.5				1			2	
48	Powwow River					6.2	7.0	6.8	3	2	2		1	1	<1
49	Cobbler Brook			6.8		5.0	7.7	6.8			2		6	8	5
51	Nissitissit River					6.5	7.2	9.3	<1	<1	2		1	<1	<1
55a	Hickory Hills Lane		6.3	6.2						<1	<1				
60	Hop Brook		6.2	5.6		6.8	6.8	6.8	2	2	<1		3	2	<1
82	Long Pond					6.5							9	<1	
85	Johnson Pond Trib														

Table 12
Merrimack River Basin
Water Quality Data 1973-1974
Group 2 - Public Water Supply Streams

Station	Water Source	Total Coliform							Fecal Coliform								Chlorides						
		Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Dec	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
2	Forbes	0	0	0		40	120	0	0	0	0			1	0	0	215	32	<10				
11	River Meadow Brook	2500	7000	60	3100	750	340	11	100	630	2		190	42	107	0	45	52	60	140	35	37	40
11a	Black Brook			1800	90	3600	200	200			200		6	42	13	71			125	96	97	118	110
11b	River Meadow Brook				770	590	530	3200					160	12	103	400				42		36	45
11c	River Meadow Brook				103	340	190	3900					54	23	40	14				32	24	26	30
11d	Putnam Brook				350	9100	400	3400					46	89	240	150				34	35	34	40
11e	Farley Brook				100	130	350	210					19	6	44	110				47	37	35	35
11f	Beaver Brook				450	1230	220	3100					66	18	138	120				56	110	104	110
11g	Pond Brook					34	1200	60						0	1	40					44	55	45
11h	Beaver Brook					360	1600	2300						0	17	220					44	42	35
23	Crystal Spring Brook	480		34					23		4						20		20				
28	Fish Brook			3700							430								60				
33	Black Brook	200	430,000	200					10	11,400	3						160	<10	180				
34	Black Brook	7000	1,100,000	400		66	200	1700	560	15,100	2			4	30	72	175	290	215		90	110	135
37	Tailor Brook	4500	3400	1600					200	510	340	19					40	60	50				
44a	Merrimack River					8100	3700	29,000						660	2300	330					11	<10	<10
50a	Kettle Br Res Trib				81	113	36						13	1	60					<10	<10	<10	
64	Waushacum Pond Trib		3600	70	18	105	6	560		42	4		4	5	33	70	40	70	51	50	47	30	35
65	Johnson Brook			510					11		2								11				
65a	Lake Cochichewick Tr.			430		72	59	2700			2		100	4	34	420			11			30	30
65b	Lake Cochichewick Tr.			1700		24	180	130			17		240	23	50	4			18		32	23	20
65c	Lake Cochichewick Tr.					11	17	4700					12	1	8	1200					11	20	15
67	Nagog Brook Trib	2200	10,100	3000		380	2200	3700	204	1550	200		20	3	23	750	36	45	23		27	28	20
67a	Nagog Pond Trib			610		14	100	120			34			0	1	15			<10		24	18	15
67b	Nagog Brook Trib			3000		880	2300	890				1	40	3	750	660			34		11	12	15
67c	Nagog Brook Trib			790		490	370	1300				1	17	4	23	500			22		19	27	20
67d	Nonset Brook Trib			460		8	1500	20				0		1	160	2			<10				25
67e	Nonset Brook Trib					0	830	1500						0	9	930			21		<10	<10	15
68	Nashoba Brook	500	3200	6300		40	270	450	75	83	114			10	29	150	27	29	23		22	25	15
69	Stony Brook			720		55	0	260			330			19	0	5			31		29	30	30
70	Boutwell Brook	1800	37,000	3000		670	14,000	390	17	1850	360			180	14,200	240	27	30	26		34	38	28
74	Maple Meadow Brook			150	300						27		0						48	38			
76	Chaffin Pond Trib	750	820	42	49	132	0		54	0	1		1	0	0		<10	40	42	32	<10	<10	
77	Poor Farm Brook	450	1030	41	40	117	2		93	46	3		2	0	0		<10	11	12	<10	<10	<10	
78	Lake Quinsigamond	3900	7400						157	200							30	34	37				
79	Scarlett's Brook	7500	240	160	80	74	15	27	54	16	33		22	5	37	15	85	85	78	64	60	64	40
79a	Gates Brook				1240								35							33			

Table 12 (Cont.)

Group #2

Station	Water Source	Total Coliform Aug	Sept	Nov	Jan	Mar	Apr	May
79b	Gates Brook				190	97	45	59
80	Scarlett's Brook Trib	630			400			
83	Long Pond Trib					260		
86	Gates Brook Trib				300		20	45
87	Chaffin Pond Trib				25000	1600	230	360
91a	Asnebumskit Brook					470	780	460
91b	Tannery Brook Trib					340	200	830
100	Quinapaxet Trib							120

Station	Water Source	Fecal Coliform Aug	Sept	Nov	Dec	Jan	Mar	Apr	May
79b	Gates Brook					24	11	45	63
80	Scarlett's Brook Trib	95				23			
83	Long Pond Trib						2		
86	Gates Brook Trib					57		54	37
87	Chaffin Pond Trib					141	300	1300	250
91a	Asnebumskit Brook						200	1500	250
91b	Tannery Brook Trib						46	470	330
100	Quinapaxet Trib								11

Station	Water Source	Chlorides Aug	Sept	Nov	Jan	Mar	Apr	May
79b	Gates Brook				72	64	115	45
80	Scarlett's Brook Trib	70			48			
83	Long Pond Trib					50		
86	Gates Brook Trib				33	40	39	35
87	Chaffin Pond Trib				18	16	18	15
91a	Asnebumskit Brook						39	20
91b	Tannery Brook Trib						<10	<10
100	Quinapaxet Trib							15

Table 12 (Cont.)

Station	Water Source	Nitrates							Phosphorous							Specific Conductance						
		Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
2	Forbes	25	2	2												861	200	108			189	218
11	River Meadow Brook	3	2	60	13	3	3	2	.03	.04						276	273	782	750	180	490	450
11a	Black Brook			3	9	7	3	<1										550	470	441	187	208
11b	River Meadow Brook				4		2	3											245		147	160
11c	River Meadow Brook				3	2	2	2											197	137	220	230
11d	Putnam Brook				6	5	3	4											268	222	223	230
11e	Farley Brook				8	5	4	5											323	230	470	480
11f	Beaver Brook				6	8	7	6											318	478	290	214
11g	Pond Brook					2	14	2						.1						200	214	174
11h	Beaver Brook					8	6	6												224		
23	Crystal Spring Brook	2		1							<.01					133		165				
28	Fish Brook			<1							<.01							325				
33	Black Brook	1	2	1					.03	.45	.01					784	70	1325				
34	Black Brook	1	<1	2		6	3	2	.02	.46	.01			.08		1378	1768	1430		402	454	520
37	Tailor Brook	1	1	2												366	383	410				
44a	Merrimack River					1	<1	<1												67	50	53
50a	Kettle Br Res Trib				4	2	1												124	78	76	
64	Waushacum Pond Trib	4	4	3	9	7	3	3								370	252	310	306	270	179	303
65	Johnson Brook			<1							.01							153				
65a	Lake Cochichewick Tr.			2			3	2			.03			<.01				208			163	164
65b	Lake Cochichewick Tr.			<1		4	3	1			.02		.06	<.01				155		196	153	119
65c	Lake Cochichewick Tr.					2	4	1					.11	.02						88	84	81
67	Nagog Brook Trib	7	7	2		2	3	2								300	367	180		152	167	115
67a	Nagog Pond Trib			<1		<1	<1	<1										408		122	102	100
67b	Nagog Brook Trib			7		<1	<1	1										328		68	73	100
67c	Nagog Brook Trib			2		2	3	2										180		121	164	113
67d	Nonset Brook Trib			<1				2										60				137
67e	Nonset Brook Trib			13		<1	<1	1										195		32	59	95
68	Nashoba Brook	2	3	1		1	1	<1	.03	<.01						180	196	165		122	140	105
69	Stony Brook			1		1	1	1										220		169	182	167
70	Boutwell Brook	<1	<1	2		3	1	1	.02	.03						201	180	180		170		
74	Maple Meadow Brook			2	<1													305	178			
76	Chaffin Pond Trib	<1	8	15	20	<1	<1									279	273	274	258	30		
77	Poor Farm Brook	<1	2	<1	1	1	<1									9660	72	82	62	55		
78	Lake Quinsigamond	1	1	1					<.01		<.01					208	216	232				
79	Scarlett's Brook	9	10	8	13	10	10	7	<.01							425	465	410	382	322		
79a	Gates Brook				15														255			

Table 12 (Cont.)

Station	Water Source	Nitrates Aug	Nitrates Sept	Nitrates Nov	Nitrates Jan	Nitrates Mar	Nitrates Apr	Nitrates May	Phosphorous Aug	Phosphorous Sept	Phosphorous Nov	Phosphorous Jan	Phosphorous Mar	Phosphorous Apr	Phosphorous May	Specific Conductance Aug	Specific Conductance Sept	Specific Conductance Nov	Specific Conductance Jan	Specific Conductance Mar	Specific Conductance Apr	Specific Conductance May
79b	Gates Brook				14	12	8	8											415	355		
80	Scarlett's Brook Trib	9			20				<.01							412			428			
83	Long Pond Trib					4														282		
86	Gates Brook Trib				32	25	18	30											335	294		
87	Chaffin Pond Trib				4	2	2	1											124	92		
91a	Asnebumskit Brook						2	1														
91b	Tannery Brook Trib						8	7														
100	Quinapaxet Trib							1														

Table 12 (Cont.)

Station	pH Aug	pH Sept	pH Nov	pH Jan	pH Mar	pH Apr	pH May	Color Aug	Color Sept	Color Nov	Color Jan	Color Mar	Color Apr	Color May	Turbidity Aug	Turbidity Sept	Turbidity Nov	Turbidity Jan	Turbidity Mar	Turbidity Apr	Turbidity May
2	6.8	6.6	6.4					3	3	2					.12	.80	.42				
11	6.9		3.0	6.6	6.6	6.5	7.0	50		12	12	45	50	50				2.0	1.0	.4	.5
11a			6.6	6.2	6.6	6.6	6.8			30	50	27	35	30			2.4	1.8	23	2	1.6
11b				6.3		6.6	6.8				45		52	50				.62		.35	.95
11c				6.3	6.6	6.6	6.8				>50	50	50	>50				.80	1.2	.4	1.8
11d				6.6	6.9	6.8	7.1				30	37	50	50				5.5	1.7	.7	.55
11e				6.4	7.0	6.8	7.0				15	27	47	35				3.0	2.7	.9	.45
11f				6.7	6.9	6.9	7.0				45	12	13	10				.68	2.8	.6	.7
11g					6.4		6.4					>50		30					.77		1.6
11h					6.8	6.6	6.5					13	7	30					.72	.6	1.0
23	6.9		6.9					13		13					.45						
28			7.0							5											
33																					
34					6.8		7.0					27							1.6		
37	7.0	6.8	7.0					>50	55	30					6.0	7.0	5.5				
44a					6.1	6.2	6.3					7	7	13							
50a				6.0	6.6	6.2					>50	45	>50					.55	.88	1.2	
64	7.2	7.2	7.1	6.7	7.5	6.8	7.0	13	13	24	3	9	27	3	.55	2.2	.9	.95	.9	.3	2.5
65																					
65a							6.8							17							.9
65b					6.9							3									
65c					6.6		6.6					22		40							1.3
67	7.2	7.2	6.8		6.9	6.4	6.6	50	48	>50		50	>50	>50	1.2	1.8	2.4		6.8	.6	3.5
67a			6.9		6.6	6.4	6.4			13		4	3	0			9.5		1.5	1.3	2.8
67b			6.6		6.2	6.2	6.6			13		>50	>50	>50			1.0		19	1.4	2.2
67c			6.6		6.8	6.4	6.6			>50		>50	>50	>50			1.0		8.5	.8	3.7
67d			6.5				7.0			>50				0			1.3				100
67e			6.6		5.3	6.6	6.8			50		0	37	3			1.8		.4	.7	45
68	6.8	6.6	6.6		6.4	6.8	6.7	50	40	45		50	50	50					.53		1.5
69			7.2		6.8	6.7	7.0			12		22	30	12			2.5		.7	.8	1.0
70	7.2	6.4	6.4		6.4	6.4	6.6	33	40	35		17	30	35			4.8		1.2	.8	5.0
74			7.0	5.0						20	>50						1.0	4.2			
76	5.3	7.0	6.6	6.4	5.2	5.0		>50	>50	10	8	5	10		.9	6.4	1.8	2.0	.3	.5	
77	5.4	6.4	6.0	5.7	6.4	6.0			25	>50	22	17	28		.8	1.0	.5	.36	.5	.6	
78		6.8	7.0						10	6						.45					
79		7.2	7.4	7.2	7.4	7.2	7.3		2	10	4	3	7	20		.25	.34	.60	.5	.4	.8
79a				6.7							3							.50			

Table 12 (Cont.)

Station	pH							Color							Turbidity						
	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
79b				6.7	6.7	7.0	7.4				13	13	12	15				.55	.9	.5	1
80				6.7							2							.5			
83					6.9							10							.47		
86				6.8	7.0	7.0	7.2				3	3	0	3				1.8	.65	.25	.6
87				5.8	7.4		6.4				15	20		13				.4	.7		.6
91a						2.7	8.6						2	3						1.5	1.2
91b						5.5	5.2						50	> 50						.6	.45
100							7.1							0							.3

Table 12 (Cont.)

Station	Chromium Aug	Chromium Sept	Chromium Nov	Chromium Jan	Chromium Mar	Chromium Apr	Chromium May	Silver Aug	Silver Sept	Silver Nov	Silver Jan	Silver Mar	Silver Apr	Silver May	Copper Aug	Copper Sept	Copper Nov	Copper Jan	Copper Mar	Copper Apr	Copper May
2	0	0	0					0	0	0					1.3	.39	.30				
11			0	0	0	0				0	0	0	0				.068	.013	.024	.014	
11			0	0	.012	0				0	0	0	0				.008	0	.077	.024	
11b				0		0					0		0					0		.009	
11c				0	0	0					0	0	0					0	.004	.009	
11d				0	.02	0					0	0	0					0	.009	.009	
11e				0	0	0					0	0	0					0	.009	.004	
11f				0	0		0				0	0	0					0	.019	.014	
11g					0	0	0					0		0					.009		.014
11h					0							0	0	0					.014	.014	.02
23	0							0							.007						
28																					
33																					
34					0							0							.024		
37	0	0	0					0	0	0					.013	.004	.22				
44a																					
50a				0	0	0					0	0	0					.013	.014	.014	
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.054	.021	.009	.08	0	.009	.014
65																					
65a																					
65b																					
65c																					
67	0	0	0		0	0	0	0	0	0		0	0	0	.027	.025	.044		.022	0	.02
67a			.02		0	0	0			0		0	0	0			.026		0	.014	.022
67b			0		.009	0	0			0		.003	0	0			.067		.014	.009	.03
67c			0		0	0	0			0		0	0	0			.008		.009	.009	.022
67d			0				0			0				.034			0				.022
67e			0		0	0	0			0		0	0	0			.022		.004	.009	.01
68			0		0		0			0		0		0			.18		.009		.014
69			0		.003	0	0			0		0	0	0			.15		0	.004	.014
70			0		0	.009	0			0		0	0	0			.08		.009	.014	.01
74			0	0		0				0	0						.10	0			
76	0	0	0	0	0	0		0	0	0	0	0	0		.020	.026	0	.008	.014	.009	
77	0	0	0	0	0			0	0	0	0	0	0		.027	.008	.053	.003	.014	.009	
78		0							0							.021					
79		0	.02	0	0	0	0		0	0	0	0	0	0		.012	0	0	.009	.009	0
79a				0							0							0			

Table 12 (Cont.)

Station	Chromium Aug	Sept	Nov	Jan	Mar	Apr	May	Silver Aug	Sept	Nov	Jan	Mar	Apr	May	Copper Aug	Sept	Nov	Jan	Mar	Apr	May
79b				0	0	0	0				0	0	0	0				0	.014	.009	0
80				0							0							0			
83					0							0							.009		
86				0	0	0	0				0	0	0	0				0	.009	.009	.01
87				0	0		0				0	0		0				0	0		.02
91a						0	.01						0	0						12.3	14
91b						0	0						0	0						.009	.014
100							0							0							.01

Table 12 (Cont.)

Station	Manganese							Lead							Iron						
	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
2	.03	.009	.012					0	0	0					.21	.45	.20				
11			.24	.49	.036	.047				0	0	0	0				.57	1.1	.31	.33	
11a			.11	.07	.35	.063				.068	0	.083	0				.9	1.25	6.2	.55	
11b				.061		.055					0		0					.30		.37	
11c				.040	.025	.047		1			0	.021	0					.31	.26	.40	
11d				.11	.067	.059					0	.021	0					1.1	.445	.68	
11e				.37	.20	.17					0	.011	0					1.7	.63	.68	
11f				.11	.071	.059					0	0	0					.29	.64	.50	
11g					.025		.03					.021		0					.20		.3
11h					.10	.083	.1					.021	.042	0					.16	.31	.4
23	.081							0							.56						
28																					
33																					
34					.067							.021							.42		
37	.30	.18	.27					0	0	0					3.8	3.2	2.5				
44a																					
50a				.029	.015	.018					0	0	0					.25	.16	.35	
64	.010	.021	.12	.079	.039	.032	.15	0	0	0	0	0	0	0	.063	.63	.59	.41	.034	.20	.17
65																					
65a																					
65b																					
65c																					
67	.54	.86	.46		.24	.4	.28	0	0	.020		.021	.021	0	1.0	.71	1.1		.69	.69	0
67a			.037		.016	.011	.03			.044		0	0	0			1.1		.10	.095	2
67b			.54		.029	.055	.14			0		.021	0	0			.61		1.5	.82	0
67c			.46		.11	.47	.24			0		0	0	0			.84		.51	.95	1.4
67d			.006				.7			0				.065			.17				17.5
67e			10.5		.018	.31	.4			0		0	0	0			2.9		.042	1.9	6.1
68			.06		.015		.084			.044		0		0			.45		.15		.6
69			.034		.043	.043	.06			0		0	0	0			.26		.23	.2	.2
70			.050		.036	.11	.06			0		0	0	0			.48		.30	.69	1
74			.034	.17						0	.067						.49	1.2			
76	.082	.67	.40	.23	.051	.051		0	0	0	0	0	0		.94	5.2	2.5	1.3	.049	.21	
77	.07	.52	.033	.025	.018	.015		0	0	0	0	0	0		.81	.37	.22	.065	.049	.088	
78		.012							0							.052					
79		.026	.069	.11	.083	.08	.08		0	.044	0	0	0	0		.077	.18	.21	.21	.28	.3
79a				.70							0							.21			

Table 12 (Cont.)

Station	Manganese							Lead							Iron						
	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
79				.096	.055	.055	.056				0	0	.031	0				.22	.18	.25	.5
80				.074							0							.13			
83					.22							0							.089		
86				.21	.20	.19	.2				0	0	0	0				.49	.37	.25	.4
87				.029	.018		.014				0	0		0				.11	.075		.26
91a						.032	.025						1.2	1.2						.11	.18
91b						.12	.12						0	0						.049	.5
100							.3							0							.3

Table 12 (Cont.)

Station	Cobalt Aug	Sept	Nov	Jan	Mar	Apr	May	Cadmium Aug	Sept	Nov	Jan	Mar	Apr	May	Zinc Aug	Sept	Nov	Jan	Mar	Apr	May
2	0	0	0					0	0	0					.20	.052	.045				
11			0	0	0	0				0	0	0	0				1.6	.18	.15	.03	
11a			0	0	0	0				0	0	0	0				.078	6.5	.13	.007	
11b				0		0					0		0					.095		.018	
11c				0	0	0					0	0	0					.12	.079	.05	
11d				0	0	0					0	0	0					.045	.05	.12	
11e				0	0	0					0	0	0					.058	.075	.075	
11f				0	0	0					0	0	0					.069	.078	.03	
11g					0		0					.003		0					.099		.07
11h					0	0	0					0	0	0					.035	.02	.013
23	0							0							.019						
28																					
33																					
34					0							0							.044		
37	0	0	0					0	0	0					.031	.04	.034				
44a																					
50a				0	0	0					0	0	0					.082	.013	.016	
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.024	.039	.038	.057	.013	.016	.06
65																					
65a																					
65b																					
65c																					
67	0	0	0		0	0	0	0	0	0		0	0	0	.032	.029	.042		.009	.13	.07
67a			0		0	0	0			0		0	0	0			.057		.057	.062	.06
67b			0		0	0	0			0		0	0	0			.021		.007	.072	.02
67c			0		0	0	0			0		0	0	0			.022		.011	.038	.01
67d			0				.02			0				0			.011				.045
67e			0		0	0	0			0		0	0	0			0		.016	.011	.02
68			0		0		0			0		0		0			.06		.14		.023
69			0		0	0	0			0		0	0	0			.078		.069	.011	.006
70			0		0	0	0			0		0	0	0			.078		.13	.12	.13
74			0	0						0	0						.14	.16			
76	0	0	0	0	0	0		0	0	0	0	0	0		.029	.12	.018	.094	.025	.072	
77	0	0	.003	0	0	0		0	0	.002	0	0	0		.024	.016	.021	.075	.023	.016	
78		0							0							.040					
79		0	0	0	0	0	0		0	0	0	0	0	0		.047	.015	.025	.016	.023	.01
79a				0							0							.058			

Table 12 (Cont.)

Station	Cobalt							Cadmium							Zinc						
	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
79b				0	0	0	0				0	0	0	0				.065	.013	.13	.13
80				0							0							.013			
83					0							0							.059		
86				0	0	0	0				0	0	0	0				.58	.020	.018	.01
87				0	0		0				0	0						.082	.020		.1
91a						0	0						0	0						.094	.07
91b						0	0						0	0						.028	.08
100							0							0							.013

Table 12 (Cont.)

Station	Aug	Sept	Nov	Jan	Mar	Apr	May
				Nickel			
2	–	0	0				
11			0	0	0	0	
11a			0	0	0	0	
11b				0		0	
11c				0	0	0	
11d				0	0	0	
11e				0	0	0	
11f				0	0	0	
11g					0		0
11h					0	0	0
23	0						
28							
33							
34					0		
37	0	0	0				
44a							
50a				0	0	0	
64	–	0	0	0	0	0	0
65							
65a							
65b							
65c							
67	–	0	0			0	0
67a			0		0	0	0
67b			0		0	0	0
67c			0		0	0	0
67d			0				.001
67e			0		0	0	0
68			0		0		0
69			0		0	0	0
70			0		0	0	0
74			0	0			
76	–	0	0	0	0	0	
77	–	0	.013	0	0	0	
78		0					
79		0	0	0	0	0	0
79a				0			

Table 12 (Cont.)

Station	Aug	Sept	Nov	Nickel Jan	Mar	Apr	May
79b				0	0	0	0
80				0			
83					0		
86				0	0	0	0
87				0	0		0
91a						0	0
91b						0	0
100							0

Table 13
Merrimack River Basin
Water Quality Data 1973-1974
Group 3 - Other Feeder Streams

		Total Coliform							Fecal Coliforms								Chlorides						
Station	Water Source	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Dec	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
4	Nonacoicus Brook	4200	260	400	37				80	20	16		6				36	36	34	<10			
5	James Brook	500	1500	16,000	10	40	4000	320	200	170	14		3	1	170	450	40	50	42	100	90	50	35
6	Wrangling Brook	700	430	620	10				200	12	41		4				10	<10	11	49			
7	Bare Meadow Brook	7000	9300						300	700							60	126					
7a	Crystal Lake Trib																						
8	Webb Brook	300	31,000	3900	2600			1600	300	380	150		33			130	44	69	52	96			65
10a	Concord River			280							39								38				
10b	Concord River			1900	1600						130		300						31	32			
12	S Lancaster Brook			100,000	410,000	270,000	440,000	440000			10,900		1800	12,500	47,000	36,000			10	22	<10	10	<10
13	Wekepeke Brook			130	16						28		1						12	10			
13a	Sudbury River			350							47								38				
13b	Concord River			1100							370								34				
20	East Meadow River	200	900	2500		250	120	160	62	74	56			33	44	33	21	18	82		26	24	25
21	Johnson Brook	200	1300	2000		27		270	21	270	349			5		29	25	25	24		16	15	20
29	Shawsheen River	1000	2700	2600					10	500	710						48	40	50				
31a	Harris Brook			10															22				
52	Reedy Meadow Brook	1000	75,000	520		310	850	190	17	4600	70			31	260	79	15	14	11		<10	15	15
53	Fall Brook	19,000	340	470					220	32	29						27	37	38				
55b	Catacoonamug Brook			3300							660								44				
56	Catacoonamug Brook	200	160	120		31	200	100	17	11	10			1	40	35	17	19	19		19	18	20
57	Catacoonamug Brook	19,000	230	500		21	570	130	200	10	22			4	65	89	21	24	19		20	20	20
61	Rawson Hill Brook	1600	7000	170		90	88	87	200	410	36			0	9	3	40	32	23		19	25	10
61a	Rawson Hill Brook					430	65	590						2	2	5					19	26	15
66	Squanacook R Trib			440							16								<10				
66a	Squanacook River			200								7							<10				
71	Webb Brook	1100	5500	3100	270	82	31	370	100	490	260		54	7	21	110	70	60	52	68	70	70	60
72	Shawsheen R Trib	3000	2000	4000	160	28	33	370	88	100	800		24	7	22	240	75	65	42	76	32	38	20
72a	Shawsheen R Trib			8000	20	53	30	17			2200		1	13	12	48			32	34		30	20
73	Strong Water Brook	500	2000	42,000	60				100	310	2400		16				40	35	32	41			
75	Lubber Brook			430	540						65		6							34			

Table 13 (Cont.)

Station	Water Source	Nitrates							Phosphorous							Specific Conductance						
		Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May	Aug	Sept	Nov	Jan	Mar	Apr	May
4	Nonacoicus Brook	<1	<1	<1	1				.02	.04	<.01	.03				210	255	235	165			
5	James Brook	<1	<1	1	5	15	12	1	.37	.07	.03	.04	.01	.17	.03	371	395	328	358	451	278	211
6	Wrangling Brook	<1	1	1	2				.03	.04	<.01	.03				147	145	133	155			
7	Bare Meadow Brook	2	3						.01	.07						270	285					
7a	Crystal Lake Trib																					
8	Webb Brook	2	2	3	9			4	.01	.02	.10	.22			.03	357	433	348	488			355
10a	Concord River			3							.13							255				
10b	Concord River			3	3						.17	.09						232	205			
12	S Lancaster Brook			4	6	4	3	3			.36	.17	.22	.11	.23			183	155	124	121	121
13	Wekepeke Brook			3	2						<.01							140	108			
13a	Sudbury River			2							.10							258				
13b	Concord River			4							.15							250				
20	East Meadow River	1	1	1		2	<1	1	.01	<.01	<.01		.06	.03	.02	177	179	455		156	125	144
21	Johnson Brook	2	2	3		2	2	1	.02	<.01	.01		.04	<.01	.01	215	215	222		135	119	130
29	Shawsheen River	2	<1	4					.10	.05	.03					276	260	285				
31a	Harris Brook			<1							.02							150				
52	Reedy Meadow Brook	<1	1	2		<1	1	1	<.01	.06	<.01		.01	.02	.07	131	140	136		94	90	82
53	Fall Brook	2	1	2					.11	.03	.01					208	230	225				
55b	Catacoonamug Brook			1							.13							270				
56	Catacoonamug Brook	<1	<1	<1		<1	1	<1	.01	.02	<.01		.01	<.01	.01	125	145	142		126	116	120
57	Catacoonamug Brook	1	1	3		1	2	1	.03	.02	.03		.01	.02	.01	137	166	157		120	132	123
61	Rawson Hill Brook	1	2	2		3	2	<1	.05	.01	.02		.01	.02	.02	173	200	158		120	118	105
61a	Rawson Hill Brook					<1	1	<1					.02	<.01	.03					105	119	98
66	Squanacook River Trib			<1							<.01							54				
71	Webb Brook	2	3	2	7	7	5	4			.18	.06	.02	.03	.02	362	368	300	406	376	349	338
72	Shawsheen River Trib	<1	<1	2	7	3	2	<1				.08	.02	.06	.03	424	393	245	356	184	205	170
72a	Shawsheen River Trib			3	6		3	<1			.08	.06		.04	.13			320	265		173	171
73	Strong Water Brook	11	6	5	8						.06	.11				276	236	225	258			
75	Lubber Brook				5							.04							215			
66a	Squanacook River			1							.03							60				

For raw water used as a public water supply after complete conventional treatment the criteria is: (35)

fecal coliform not to exceed 2,000 per 100 ml;
total coliform not to exceed 10,000 per 100 ml.

Conventional treatment is defined as: coagulation, sedimentation, rapid granular filtration, and disinfection.

Only station 2 meets the raw water criteria for use as a public water supply after disinfection. Sampling stations that do not meet water supply criteria for use as a raw water supply after conventional treatment are: stations 33, 34, 70, and 87. These stations exceed the 10,000 counts/ 100 ml limit on total coliform. All the remaining Group 2 stations (water supply) would need complete conventional treatment before they were used as a water supply, based on bacteriological considerations.

The proposed EPA chemical water quality criteria for raw water used as a public water supply is: (35)

Chlorides	250 mg/1
Nitrates N	10 mg/1
pH	5.0 - 9.0
Color	75 units (Co-Pt)
Chromium	0.05
Silver	0.05
Copper	1.0
Manganese	0.05
Lead	0.05
Iron	0.3
Cadmium	0.01
Zinc	5.0

Stations 11a, 11c, 37, 50a, 67, 67b, 67c, 67d, 74, 76, 77 all have color levels greater than 50 units. Stations 11, 11a, 11d, 11e, 11f, 34, 37, 64, 67, 67b, 67c, 67e, 68, 74, 76, 77, 86, and 42 violate both iron and namganese limits. Stations 2, 67a, and 70 violate iron limits only while stations 11b, 23, 79, 79b, 80, and 83 violate manganese limits only.

Approximately 75% of the current surface water supplies in the Merrimack River Basin employ chlorination as the only method of treatment. The Department of Public Health requires all new surface supplies to include complete conventional treatment.

The group 3 feeder streams had two stations which have high coliform counts and could present a public health hazard. They are stations 12 and 52.

Since this sampling program was conducted to identify problem areas and to analyze the reason for this condition, each station which does not meet the assigned standard for its group use will be discussed. Additional information of sanitary conditions upstream from these trouble spots would be needed to pinpoint the exact location of the problem and the single cause of the contamination.

Group 1, recreational streams, will be discussed first. Stations 17 and 17b are located on tributaries of Round Meadow Pond in Westminster. The area is moderately populated utilizing on-lot sewage facilities. No industries or direct point discharges were noted. Failing individual land disposal systems are assumed to be the cause of this pollution and sewering of this area should eliminate the contamination.

Station 21a is located on the Merrimack River. The river is bordered by Haverhill on the north and Groveland on the south, both are densely populated areas and Haverhill has industries which discharge directly into the Merrimack River. Both cities are currently installing collection systems and a joint secondary treatment facility for sanitary and industrial wastes.

Bolton Center Brook (station 24) flows through the center of Bolton and is bordered by homes utilizing on-lot disposal systems. The close proximity of these systems and the lack of any other pollution sources results in the conclusion that there are failing disposal systems leaching into the brook.

Station 30 is located in the Spicket River just below the Lawrence General Hospital, which has a direct point source discharge. The analysis for station 31 upstream of this discharge does not indicate pollution. The river also passes through the City of Lawrence between stations 31 and 30. Station 30d is in the Merrimack River at Methuen, Ma. just upstream of the Spicket River. Methuen is densely developed.

Stony Brook in Chelmsford (station 43) has a direct industrial waste discharge which could be the source of contamination.

Station 45 is located on a tributary to Mascuppic Lake and passes through a large subdivision with an on-lot sewage disposal system. The current water quality data suggests that these systems are causing pollution problems in this tributary and may eventually effect the lake.

Cobbler Brook, station 49, flows through the town of Merrimac which is served by on-lot sewage disposal systems. No major industries are located in this area. The alternative plans call for a municipal sewerage system in this area which should eliminate the water quality problems in the brook.

Station 51 is on the Nissitissit River in Pepperell. The area is moderately developed with on-lot land disposal systems. There are also some industries in the town.

These stations which show high bacterial counts, high nitrate and high phosphorus concentrations are all located in streams that flow by or through moderately or densely populated areas. These areas are primarily served by on-lot disposal systems. This indicates that these individual disposal systems may not be functioning properly, that the area is over developed for the soil conditions, or that the systems were poorly designed. The proposed alternatives will sewer and treat waste from the towns of Groveland, Lawrence, Methuen, Chelmsford, Tyngsboro, Merrimac, and Pepperell and should alleviate the pollution problems at stations 21a, 30, 30d, 43, 45, 49, and 51. However, it should be realized that sewerage systems may not always be the best answer to the problem, and would not be necessary if on-lot systems were well designed and development was well planned taking into consideration the soils capacity to accommodate on-lot disposal systems.

The public water supply streams (group 2) that do not meet standards are stations 33, 34, 70 and 87.

Stations 33 and 34 are on Black Brook in Lowell. Sources of these pollutants appear to be coming from the Lowell incinerator and the solid waste disposal site. Flooding of this area has occurred.

Station 70 is located on Boutwell Brook in Westford, Mass. This brook flows through a developed area of Westford called Graniteville which is served by on-lot sewage disposal systems. There are industries and homes located along the brook. The alternatives propose sewerage collection and treatment of this areas waste by 1990 and 2020.

Station 87 is located on a feeder stream to Wachusett Reservoir in the town of Holden. Upstream of this station is a large subdivision served by on-lot sewage disposal systems. The soil in this area is classified as severe limitation soil. The subdivision has a history of overflowing sewage system according to town officials.

Station 91a on Asnebumskit Brook in Holden showed the greatest source of chemical pollution recorded in this study. Samples collected at a point source discharge to the brook recorded the following analysis:

	Copper	Fluoride	Lead	pH	Specific Conductance
March 1974	120 mg/1	65 mg/1	500 mg/1	9.5	948 microholms
April 1974	12.3 mg/1		1.2 mg/1	2.7	669 microholms
May 1974	14.0 mg/1		1.2 mg/1	8.6	808 microholms

This brook is a tributary to Wachusett Reservoir and a source of ground water recharge for the town of Holden gravel packed well. This point discharge is from an electro-plating industry located on the brook.

Those sources showing high iron and manganese analysis should be reviewed before use. Iron and manganese limits are not set for health reasons, rather they are set for esthetic considerations such as color staining in laundry operations.

There are a few stations which do not exceed the recommended standards but which have analysis data high enough to be included in this discussion. Additional data is needed to analyze the problems and to determine if the pollution levels are rising.

Stations 11, through 11h are located either on River Meadow Brook or on a tributary to River Meadow Brook in Chelmsford. Six water supply wells are located along this brook. Several data points show chloride concentrations over 100 mg/1, nitrate concentrations between 2 and 70, color of greater than 50 units, and total coliforms exceeding 3,000 counts per 100 ml. Station 11 had specific conductance levels up to 782 microholms and iron concentrations up to 6.2 mg/1. Homes and industries in this area are served by on-lot waste disposal systems and the source of this pollution is thought to be failure in these systems.

Stations 67, 67b and 67c in Acton are on tributaries to Nagog Brook. The total coliforms are greater than 2,000 counts/100 ml in several cases with one reading at 10,100; fecal coliforms are greater than 500 counts per 100 ml with one reading at 1550 counts per 100 ml; nitrates are up to 7 mg/1; and color is greater than 50 units at several data points. This area has been developed within the past five years and apartment houses and condominiums have been constructed along both sides of the stream. The area behind the apartment buildings is swampy which suggests that the sewage disposal area has been filled. These dwellings use on-lot land disposal systems to dispose of their sewage. Station 67b is about 500 feet downstream of an apartment complex. An anaerobic sewage odor was noticed at this site and the water was gray in color.

Station 76 located in the town of Holden on a tributary to Wachusett Reservoir also had strong septic odors at the sampling location; but the coliform counts were low.

Stations 12 and 52 are the heavy pollution areas in group 3 streams. Station 12 is located on South Lancaster Brook in Lancaster. The fecal and total coliform counts and the nitrate concentrations are high and indicative of possible sewage contamination. Atlantic Union College in the area operates a large institutional waste-disposal system and the remaining area is served by individual on-lot disposal systems. The proposed alternatives suggest sewering of this area with connection to an upgraded MDC plant at Clinton.

Station 52 is on Reedy Meadow Brook in Pepperell. This brook is a tributary of the Nashua River. High August and September coliform counts were observed. These months are indicative of low flow periods and little dilution of any pollutional load would result. These areas have proposed sewerage by 1990 according to the alternative wastewater management schemes.

Since one of the goals of Public Law 92-500 is to provide swimmable fishable water quality by 1983, the primary recreation standard of 200 counts per 100 ml, log mean; and 400 counts per 100 ml in not more than 10% of the total samples taken must be met. Sixty-five percent of the recreational water group 1, and twenty-three percent of the group 3 streams do not meet these primary standards. More information must be gathered on these streams to locate the problem areas before a solution can be developed.

Radiological data was also collected on 49 stations (stations from all three groups were included as well as stations below dumps and sewage treatment plants.) The results are shown in Table 14.

The U. S. Public Health Drinking Water Standards for radioactivity are:

Radium - 226	< 3 pCi/liter
Strontium - 90	<10 pCi/liter

In known absences of strontium - 90 and alpha emitters, the water supply is acceptable when the gross beta concentrations do not exceed 1000 pCi/liter.

All gross beta analysis were below 1,000 pCi/liter. There were five stations (stations 3, 32, 59, 79-B and 21-A), which had gross beta concentrations which exceeded 10 pCi/liter. A strontium - 90 analysis of these stations would be required to compare these to the standard. All gross alpha analysis were less than 2 pCi/liter.

TABLE 14
MERRIMACK RIVER BASIN
WATER QUALITY ANALYSES FOR RADIOACTIVITY
Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids mg/l	Undissolved Solids Gross Beta pCi/l Date Ctd. (c)	Undissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Dissolved Solids mg/l	Dissolved Solids Gross Beta pCi/l Date Ctd. (a)	Dissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Specific Gamma Activity pCi/l
St. # 15 Hager Pond # 19203	SpW-1699 5/15/74	14.0	1.1 ± 73% 8/19/74	< 2.0 8/19/74	306.0	9.0 ± 17% 8/19/74	< 2.0 8/19/74	(d)
St. # 62 Assabet R. # 19206	SpW-1700 5/15/74	19.4	1.4 ± 59% 8/19/74	< 2.0 8/19/74	332.0	7.6 ± 21% 8/19/74	< 2.0 8/19/74	(d)
St. # 61 Rawson Hill # 19208	SpW-1701 5/15/74	10.8	4.8 ± 26% 8/19/74	< 2.0 8/19/74	120.0	2.7 ± 40% 8/19/74	< 2.0 8/19/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)
Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids mg/l			Dissolved Solids mg/l			Specific Gamma Activity pCi/l
			Gross Beta pCi/l Date Ctd. (c)	Gross Alpha pCi/l Date Ctd. (b)		Gross Beta pCi/l Date Ctd. (a)	Gross Alpha pCi/l Date Ctd.(b)	
St. # 61-A Rawson Hill Brook # 19209	SpW-1702 5/13/74	6.0	2.4 ± 45% 8/19/74	< 2.0 8/19/74	124.5	4.5 ± 26% 8/19/74	< 2.0 8/19/74	(d)
St. # 42 Second Div. Brook # 19262	SpW-1703 5/13/74	9.8	3.3 ± 32% 8/19/74	< 2.0 8/19/74	228.0	7.7 ± 19% 8/19/74	< 2.0 8/16/74	(d)
St. # 67-A Nagog Brook # 19267	SpW-1704 5/13/74	4.8	1.2 ± 73% 8/19/74	< 2.0 8/16/74	104.0	4.7 ± 24% 8/19/74	< 2.0 8/19/74	(d)
St. # 67-E Vine Brook # 19269	SpW-1705 5/13/74	89.2	7.9 ± 19% 8/19/74	< 2.0 8/19/74	39.0	4.5 ± 27% 8/19/74	< 2.0 8/19/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)

Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids			Dissolved Solids			Specific Gamma Activity pCi/l
		mg/l	Gross Beta pCi/l Date Ctd. (c)	Gross Alpha pCi/l Date Ctd. (b)	mg/l	Gross Beta pCi/l Date Ctd. (a)	Gross Alpha pCi/l Date Ctd. (b)	
St. # 70 Stony Brook # 19273	SpW-1706 5/13/74	44.0	1.2 ± 73% 8/16/74	< 2.0 8/16/74	238.0	4.3 ± 28% 8/19/74	< 2.0 8/19/74	(d)
St. # 5 Johnson Brook # 19274	SpW-1707 5/13/74	16.0	2.5 ± 42% 8/16/74	< 2.0 8/19/74	248.0	4.1 ± 30% 8/16/74	< 2.0 8/16/74	(d)
St. # 54 Nashua R. # 19278	SpW-1708 5/14/74	22.0	< 1.0 8/16/74	< 2.0 8/16/74	422.0	9.4 ± 19% 8/16/74	< 2.0 8/16/74	(d)
St. # 14-A Sawmill Pond Brook # 19280	SpW-1709 5/14/74	10.6	< 1.0 8/16/74	< 2.0 8/16/74	40.6	2.7 ± 40% 8/19/74	< 2.0 8/16/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)
Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids mg/1	Undissolved Solids Gross Beta pCi/1 Date Ctd. (c)	Undissolved Solids Gross Alpha pCi/1 Date Ctd. (b)	Dissolved Solids mg/1	Dissolved Solids Gross Beta pCi/1 Date Ctd. (a)	Dissolved Solids Gross Alpha pCi/1 Date Ctd.(b)	Specific Gamma Activity pCi/1
St. # 17-A Round Mdw. Pond # 19282	SpW-1710 5/14/74	14.0	2.0 ± 54% 8/16/74	< 2.0 8/16/74	176.0	5.9 ± 22% 8/16/74	< 2.0 8/16/74	(d)
St. # 17-B Tophet Swamp Brook # 19283	SpW-1711 5/14/74	12.0	< 1.0 8/16/74	< 2.0 8/16/74	126.6	3.6 ± 32% 8/16/74	< 2.0 8/16/74	(d)
St. # 16 Whitman R. # 19284	SpW-1712 5/14/74	9.0	< 1.0 8/16/74	< 2.0 8/16/74	80.0	4.4 ± 27% 8/19/74	< 2.0 8/16/74	(d)
St. # 51 Nissitissit R. # 19288	SpW-1713 5/14/74	107.4	2.4 ± 51% 8/16/74	< 2.0 8/16/74	135.2	< 1.0 8/16/74	< 2.0 8/16/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/1.
(c) The minimum detectable limit of gross beta is 1.0 pCi/1.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)
Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids			Dissolved Solids			Specific Gamma Activity pCi/l
		mg/l	Gross Beta pCi/l Date Ctd. (c)	Gross Alpha pCi/l Date Ctd. (b)	mg/l	Gross Beta pCi/l Date Ctd. (a)	Gross Alpha pCi/l Date Ctd. (b)	
St. # 44-A Merrimack R. # 19290	SpW-1714 5/14/74	10.6	1.8 ± 52% 8/16/74	< 2.0 8/16/74	144.0	4.0 ± 29% 8/16/74	< 2.0 8/16/74	(d)
St. #43 Stony Brook # 19292	SpW-1715 5/14/74	15.4	< 1.0 10/30/74	< 2.0 10/30/74	211.2	6.1 ± 22% 10/30/74	< 2.0 10/30/74	(d)
St. # 82 Long Pond # 19471	SpW-1716 4/17/74	15.8	1.2 ± 73% 10/30/74	< 2.0 10/30/74	361.4	6.8 ± 23% 10/30/74	< 2.0 10/29/74	(d)
St. # 30-B # 19769	SpW-1717 (No date)	17.0	1.0 ± 86% 10/30/74	< 2.0 10/30/74	194.4	2.0 ± 60% 10/30/74	< 2.0 10/30/74	(d)
St. 60 Hop Brook # 19207	SpW-1725 5/15/74	14.2	< 1.0 10/30/74	< 2.0 10/30/74	196.2	2.5 ± 49% 10/30/74	< 2.0 10/30/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)

Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids mg/l	Undissolved Solids Gross Beta pCi/l Date Ctd. (c)	Undissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Dissolved Solids mg/l	Dissolved Solids Gross Beta pCi/l Date Ctd. (a)	Dissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Specific Gamma Activity pCi/l
St. # 79 Scarlett Brook # 19211	SpW-1726 5/15/74	21.0	< 1.0 10/30/74	< 2.0 10/30/74	311.0	3.9 ± 35% 10/30/74	< 2.0 10/30/74	(d)
St. # 68 Nashoha R. # 19263	SpW-1727 5/13/74	17.8	< 1.0 10/30/74	< 2.0 10/30/74	117.6	2.4 ± 41% 10/30/74	< 2.0 10/29/74	(d)
St. # 2-A Locke Brook # 19287	SpW-1728 5/14/74	22.6	< 1.0 10/30/74	< 2.0 10/30/74	222.8	4.0 ± 34% 10/30/74	< 2.0 10/29/74	(d)
St. # 43-A Deep Brook # 19291	SpW-1729 5/14/74	16.6	< 1.0 10/30/74	< 2.0 10/29/74	151.4	3.3 ± 33% 10/30/74	< 2.0 10/30/74	(d)
St. # 36-A Chauncey Lake # 19204	SpW-1749 5/15/74	15.8	1.3 ± 76% 10/30/74	< 2.0 10/29/74	176.2	3.8 ± 30% 10/30/74	< 2.0 10/29/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)

Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids mg/l	Undissolved Solids Gross Beta pCi/l Date Ctd. (c)	Undissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Dissolved Solids mg/l	Dissolved Solids Gross Beta pCi/l Date Ctd. (a)	Dissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Specific Gamma Activity pCi/l
St. # 63 Assabet R. # 19205	SpW-1750 5/15/74	64.2	2.2 ± 44% 10/30/74	< 2.0 10/29/74	244.6	8.1 ± 19% 10/30/74	< 2.0 10/29/74	(d)
St. # 40 Assabet R. # 19261	SpW-1751 5/13/74	17.6	1.6 ± 57% 10/30/74	< 2.0 10/30/74	143.6	4.0 ± 28% 10/30/74	< 2.0 10/30/74	(d)
St. # 67 Nagag Brook # 19264	SpW-1752 5/13/74	14.0	2.0 ± 55% 10/18/74	< 2.0 10/18/74	114.0	4.3 ± 27% 10/18/74	< 2.0 10/18/74	(d)
St. # 67-B Nagag Brook # 19266	SpW-1753 5/13/74	10.0	1.5 ± 57% 10/18/74	< 2.0 10/18/74	170.0	4.7 ± 29% 10/18/74	< 2.0 10/18/74	(d)
St. # 11-G Heart Pond Brook # 19270	SpW-1754 5/13/74	5.6	1.0 10/24/74	< 2.0 10/24/74	142.4	4.5 ± 28% 10/24/74	< 2.0 10/24/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)
Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids			Dissolved Solids			Specific Gamma Activity pCi/l
		mg/l	Gross Beta pCi/l Date Ctd. (c)	Gross Alpha pCi/l Date Ctd. (b)	mg/l	Gross Beta pCi/l Date Ctd. (a)	Gross Alpha pCi/l Date Ctd. (b)	
St. # 11-H Beaver Brook # 19271	SpW-1755 5/13/74	208.0	< 1.0 10/18/74	< 2.0 10/18/74	260.0	3.8 ± 35% 10/18/74	< 2.0 10/18/74	(d)
St. # 3 Flanagan Pond # 19275	SpW-1756 5/13/74	28.0	1.8 ± 52% 10/18/74	< 2.0 10/18/74	862.0	46.0 ± 8% 10/18/74	< 2.0 10/18/74	(d)
St. # 57 Catacoonamug Brook # 19267	SpW-1757 5/14/74	6.0	< 1.0 10/18/74	< 2.0 10/18/74	568.0	3.5 ± 36% 10/18/74	< 2.0 10/18/74	(d)
St. # 56 Catacoonamug Brook # 19277	SpW-1758 5/14/74	8.0	< 1.0 10/18/74	< 2.0 10/18/74	160.0	4.2 ± 28% 10/18/74	< 2.0 10/18/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)
Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids mg/l	Undissolved Solids Gross Beta pCi/l Date Ctd. (c)	Undissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Dissolved Solids mg/l	Dissolved Solids Gross Beta pCi/l Date Ctd. (a)	Dissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Specific Gamma Activity pCi/l
St. 54-A Nashua River # 19279	SpW-1759 5/14/74	10.6	1.1 ± 89% 10/24/74	< 2.0 10/23/74	279.2	4.4 ± 29% 10/24/74	< 2.0 10/24/74	(d)
St. # 17 Round Meadow Pond # 19281	SpW-1760 5/14/74	13.4	1.5 ± 66% 8/24/74	< 2.0 8/24/74	231.6	4.4 ± 29% 8/24/74	< 2.0 8/24/74	(d)
St. # 1 Phillips Brook # 19285	SpW-1761 5/14/74	5.6	< 1.0 8/24/74	< 2.0 8/24/74	71.2	2.0 ± 47% 8/24/74	< 2.0 8/24/74	(d)
St. # 45 Mascuppic Lake # 19470	SpW-1762 4/17/74	13.2	1.1 ± 86% 10/24/74	< 2.0	213.4	4.7 ± 26% 10/24/74	< 2.0 10/24/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)

Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids mg/l	Undissolved Solids Gross Beta pCi/l Date Ctd. (c)	Undissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Dissolved Solids mg/l	Dissolved Solids Gross Beta pCi/l Date Ctd. (a)	Dissolved Solids Gross Alpha pCi/l Date Ctd. (b)	Specific Gamma Activity pCi/l
St. # 8 Webb Brook # 19742	SpW-1763 5/9/74	10.2	< 1.0 10/24/74	< 2.0 10/24/74	187.0	3.7 ± 31% 10/24/74	< 2.0 10/24/74	(d)
St. # 32 Beaver Brook # 19756	SpW-1764 5/9/74	10.0	< 1.0 10/24/74	< 2.0 10/24/74	238.6	15.4 ± 14% 10/24/74	< 2.0 10/24/74	(d)
St. # 45 Mascuppic Lake # 19757	SpW-1765 5/9/74	18.0	< 1.0 10/18/74	< 2.0 10/18/74	352.0	3.9 ± 35% 10/18/74	< 2.0 10/18/74	(d)
St. # 44 Mascuppic Lake # 19758	SpW-1766 5/9/74	7.8	< 1.0 10/24/74	< 2.0 10/24/74	68.0	2.7 ± 38% 10/24/74	< 2.0 10/24/74	(d)

(a) **The error expressed is the percentage relative 2-sigma counting error.**
(b) **The minimum detectable limit of gross alpha is 2.0 pCi/l.**
(c) **The minimum detectable limit of gross beta is 1.0 pCi/l.**
(d) **Indicates specific activity not detectable.**

TABLE 14 (Cont.)
Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids			Dissolved Solids			Specific Gamma Activity pCi/l
		mg/l	Gross Beta pCi/l Date Ctd. (c)	Gross Alpha pCi/l Date Ctd. (b)	mg/l	Gross Beta pCi/l Date Ctd. (a)	Gross Alpha pCi/l Date Ctd.(b)	
St. # 59 French Brook # 19210	SpW-1869 5/15/74	14.0	1.4 ± 66% 10/24/74	< 2.0 10/24/74	300.0	44.9 ± 7%	< 2.0 10/24/74	(d)
St. # 79-B Gates Brook # 19212	SpW-1870 5/15/74	16.0	1.4 ± 66% 10/22/74	< 2.0 10/22/74	279.2	14.8 ± 13% 10/22/74	< 2.0 10/22/74	(d)
St. # 67-C Nagag Brook # 19265	SpW-1871 5/13/74	16.8	1.4 ± 78% 10/22/74	< 2.0 10/22/74	152.0	8.8 ± 16% 10/22/74	< 2.0 10/22/74	(d)
St. # 69 Stony Brook # 19272	SpW-1872 5/13/74	10.0	< 1.0 10/22/74	< 2.0 10/22/74	162.0	5.0 ± 24% 10/22/74	< 2.0 10/22/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

TABLE 14 (Cont.)

Results of Water Analyses

Location	Sample Code & Date Collected	Undissolved Solids			Dissolved Solids			Specific Gamma Activity pCi/l
		mg/l	Gross Beta pCi/l Date Ctd. (c)	Gross Alpha pCi/l Date Ctd. (b)	mg/l	Gross Beta pCi/l Date Ctd. (a)	Gross Alpha pCi/l Date Ctd. (b)	
St. # 1-A Phillips Brook # 19286	SpW-1873 5/14/74	10.0	1.4 ± 66% 10/22/74	< 2.0 10/22/74	198.0	9.8 ± 17% 10/22/74	< 2.0 10/22/74	(d)
St. # 52 Reedy Meadow # 19289	SpW-1874 5/14/74	10.0	1.3 ± 87% 10/21/74	< 2.0 10/21/74	348.0	5.5 ± 26% 10/22/74	< 2.0 10/21/74	(d)
St. # 21-A Outfall at Merrimack R. # 19764	SpW-1875 5/8/74	22.0	1.2 ± 89% 10/22/74	< 2.0 10/21/74	358.0	10.0 ± 18% 10/21/74	< 2.0 10/21/74	(d)

(a) The error expressed is the percentage relative 2-sigma counting error.
(b) The minimum detectable limit of gross alpha is 2.0 pCi/l.
(c) The minimum detectable limit of gross beta is 1.0 pCi/l.
(d) Indicates specific activity not detectable.

I. DRINKING WATER SUPPLIES

The groundwater aquifers in Massachusetts are one of the major sources of municipal water supplies. With increases in land costs, and increases in pollution of surface supplies, groundwater will be more in demand as a water supply source.

There are many problems developing that are endangering the water quality and quantity of these aquifers. Sources of contamination are:

1. Highway encroachment
2. Urban development
3. Oil pipelines
4. Industrial dumps
5. Municipal dumps
6. Polluted streams that feed aquifers

There is also concern over the loss of groundwater recharge from on-lot land disposal systems with the installation of municipal sewage collection systems.

The groundwater supplies in Massachusetts, in general, are located in shallow aquifers of limited area. Many are located near the surface often less than ten feet from grade. These aquifers contain unconsolidated mixed sands and gravels of such porosity to allow large water withdrawals of up to 500 gallons of water per minute. Polluted waters entering the aquifers from any of the above mentioned sources, can be rapidly transported through the aquifer to the discharge point especially during times when water will be taken out of storage. These coarse sands within the aquifer allow little in the way of absorption, chemical changes or straining out of bacteria and viruses. Therefore, the areas above and around these supplies must be protected.

The Massachusetts Department of Public Health requires a 400-foot buffer zone, owned by the municipality. This area must be free from any source of pollution or polluting material. With increases in volumes and complexity of chemicals now present in the environment, there is serious thought being given to increasing the buffer zone for greater protection.

One of the major problems developing in the Basin is the heavy contamination of groundwater from road salting and salt piles.

The United States Public Health Service Drinking Water Standards considers 250 mg/l of chloride as a maximum limit for acceptable drinking water. Chlorides greater than this concentration imparts a salty taste to the water.

Before the construction of the Massachusetts Turnpike, much concern was voiced by the Massachusetts Department of Public Health concerning the encroachment of this highway on the groundwater supplies of the area. The concern centered on the large volumes of salt to be used on the highway necessary to maintain a base surface.

A recent (1973) analysis of the Town of Auburn gravel-packed wells shows the following analysis:

	Hardness	Sodium	Chloride	Specific Conductance
Well #1	264	100	235	800
2	269	150	415	1,240
3	236	50	145	560
4	146	30	86	420
5	90	10	27	240

The above analysis shows the results of highway and urban development on groundwater supplies. Eighty percent of the wells have sodium above 20 mg/l which is the recommended limit for people with kidney, heart and liver diseases and who are on sodium restricted diets. Water from wells one and two could be very distasteful, plus possibly causing digestive upset in many people.

If sewage is the source of the pollution and it is abated, the sodium and chloride ions will be reduced in concentration to acceptable levels. However, if highway salting is the cause of pollution, the concentrations may reduce in late fall and increase in spring as runoff of the salts recharges this pumping aquifer.

Probably one of the greatest causes of surface water contamination is the encroachment of urban development on the watersheds and especially the feeder streams to the surface water supplies. This encroachment from all phases of construction has brought about the serious pollution problems physical, bacterial, and chemical. Physical pollution from the runoff at construction projects or the storm drainage discharges into feeder streams of surface supplies has, and will continue to adversely affect the water quality. Turbidity in the drinking water affects chlorination and the percentage of bacterial kill. This turbidity may be from suspended soil particles or may be from algae. Increase in nutrients from upstream sources of adjacent urban development will increase algae blooms, cause taste and odor in the supply, and cause stratification of deep lakes.

J. POLLUTION OF SHELLFISH GROWING AREAS

In years past, shellfish have been a major resource of the estuaries of the Merrimack River and Plum Island sound. The extensive tidal mudflats on both the Newburyport and Salisbury sides of the Merrimack, as well as the mudflats of Plum Island Sound and its tributaries, provide an excellent habitat for the soft-shell clam. However, many of these productive areas are closed today due to the numerous sources of pollution. Although, in most areas, pollution does not affect shellfish mortality, it does affect their utilization.

Shellfish harvesting is prohibited in many areas because contaminated clams from these areas are a potential threat to the public health. Clams filter large quantities of water through their gills each day to strain out food particles; through this process, both bacteria and viruses, as well as other hazardous substances such as heavy metals, may become concentrated in the edible part of the clam, rendering them potential carriers of disease. For the most part, shellfish harvesting areas are classified on the basis of coliform bacteria counts of overlying waters.

From 1925 to 1927, all clam flats in the Merrimack estuary were closed to shellfish harvesting for human consumption due to heavy pollution of the river. On July 16, 1928, the city of Newburyport opened its shellfish dupuration plant on Plum Island so that some clam beds could be opened on a restricted basis. However, increasing pollution has closed down more areas over the years. Table 15 shows the general decline in the number of bushels processed from Salisbury and Newburyport by the shellfish depuration plant from 1935 to 1964. (16)

TABLE 15

Date	Number of Bushels	Date	Number of Bushels
1935*	23,204	1950	102
1936	13,678	1951	8
1937	11,371	1952	958
1938	13,149	1953	1,119
1939	8,327	1954	853
1940	8,778	1955	1,116
1941	3,736	1956	1,514

TABLE 15 (Cont'd)

Date	Number of Bushels	Date	Number of Bushels
1942	3,996	1957	352
1943	4,136	1958	105
1944	4,532	1959	353
1945	3,132	1960	666
1946	0	1961***	400
1947	0	1962	346
1948	884	1963	1,205
1949	969	1964	1,470

Total number of bushels processed-110,429

* Operated by the City of Newburyport (1935-1960)
** 1949 was the last year clams from the Town of Salisbury were processed
*** Operated by the Commonwealth of Massachusetts (1961 to present)

Salisbury clam flats have been closed since 1949. Today, all flats along the river are closed, leaving 962.6 acres of a potentially valuable resource undeveloped.

The portion of Plum Island Sound extending from Plum Bush Creek to Pine Island Creek in Newbury is open on a restricted basis. The area from Pine Island Creek to the Rowley River in Rowley is open to harvesting by the general public. This area contains 186.8 acres of productive flats, and 51 acres of non-productive flats. Sources of pollution must be controlled to keep these areas open to shellfish harvesting.

The Commonwealth of Massachusetts is a member of the national shellfish sanitation program for interstate shipping of shellfish, a cooperative partnership between participating states and the USPHS. Under this program, the Massachusetts Department of Public Health has the responsibility of classifying and surveying the shellfish areas in Massachusetts according to procedures specified in the National Shellfish Sanitation Program Manual of Operation, Part 1, Sanitation of Shellfish Growing Areas. The four classifications employed by the Department of Public Health are:

1. Approved: Growing areas may be designated as approved when

a. The sanitary survey indicates that pathogenic micro-organisms, radio-nuclides and/or harmful industrial wastes do not reach the area in dangerous concentrations.

b. Laboratory verification of the findings, is done whenever the sanitary survey indicates a need. The coliform median MPN of the water in approved areas should not exceed 70 per 100 ml and not more than ten percent of the samples should exceed an MPN of 230 per 100 ml in portions of the area most likely to be exposed to fecal contamination during the most unfavorable conditions. Such an area must also be protected against chance contamination with fecal material for example during a temporary breakdown in a sewage treatment facilities.

2. Restricted: An area may be classified as restricted when the sanitary survey indicates a limited degree of pollution which would make it unsafe to harvest the shellfish for direct marketing. Shellfish from such areas may be marketed after purifying or relaying.

The coliform median MPN of the water in restricted areas should not exceed 700 per 100 ml and not more than ten percent of the samples should exceed an MPN of 2300 per 100 ml in portions of the area most likely to be exposed to fecal contamination in the most unfavorable conditions. Also, the area must not contain harmful concentrations of radio-nuclides and/or harmful industrial waste. In Massachusetts, shellfish from restricted areas may be taken only by commercial diggers and must be sent to a depuration plant in Newburyport, Massachusetts to be purified before being marketed. The depuration plant in Newburyport (Formerly run by the Town of Newburyport) is run by the Massachusetts Division of Marine Fisheries to insure safety to the shellfish consumer. The cost of treating the shellfish is shared by the commercial diggers and the cities and towns from which the shellfish were obtained.

3. Prohibited Areas: An area shall be classified prohibited if the sanity survey indicates that dangerous numbers of pathogenic micro-organisms or hazardous concentrations of radio-nuclides and industrial wastes might reach the area. The taking of shellfish from such areas for direct marketing shall be prohibited. Actual or potential growing areas which have not been subjected to sanitary survey shall be automatically classified as "prohibited". An area is classified "prohibited" if the median coliform MPN is in excess of 2300 per 100 ml or the water in the area contains dangerous concentrations of industrial wastes and radio-nuclides.

4. Seasonal Areas: An area is classified as "seasonal" when it can only be classified as "restricted" during certain seasons of the year. For example, recreation areas, subject to seasonal pollution from summer houses and boats, may be only open to harvesting from November to April; during the summer months such an area would be classified as "prohibited".

A sanitary survey of each shellfish growing area must be performed prior to its approval for shellfish harvesting. The sanitary quality of the area is re-appraised every two years and resurveyed if its quality is thought to be questionable. The "National Shellfish Sanitation Program Manual of Operations" states that the purpose of a sanitary survey is to identify and evaluate those factors which influence the sanitary quality of a growing area, and which may include sources of effects of currents, winds, and tides in disseminating pollution over the growing area; the bacterial quality of water and bottom sediments; pollution bacteria in tributaries and the estuary; bottom configuration, salinity and turbidity of the water.

Since it is difficult because of time and budget limitations to collect a large number of samples from each area, it is recommended that sampling stations be chosen to provide a maximum of data, and to represent as wide an area as possible.

Sample collection should be timed to represent the most unfavorable hydrographic and pollution conditions, since shellfish respond rapidly to an increase in the number of bacteria or viruses in their environment. The Massachusetts Department of Public Health also maintains records of original surveys, re-appraisals and resurveys.

Althrough the National Shellfish Sanitation Program specified that shellfish areas are to be classified according to results obtained from both bacteriological and chemical surveys, a heavy emphasis is placed on bacteriological findings. This can be expected as there are no enforceable limits for concentrations of hazardous industrial wastes and radio-nuclides in shellfish harvesting areas.

K. CONCLUSIONS AND RECOMMENDATIONS

The results of the sanitary study and investigations carried out in this Merrimack River Basin Study, through the numerous interviews with State and local officials, field investigations and water quality monitoring of 164 sites determine a need for institutional adjustments for wastewater management at the Federal, State and local levels.

Approximately 50% of the basin population is serviced by on-lot land disposal systems. The administrative authority is vested with the State health departments and local boards of health. Local boards of of health lack the funds, the personnel and expertise required to administrate a sound wastewater management program. The designs used and the location and extent of these land systems are creating increasing amounts of pollution to our recreational and water supply waters. Land disposal and land use management cannot be separated and still maintain a pollution-free region.

The major building activities presently and predicted for the future will be done beyond municipal sewer collection systems. Thus to control pollution beyond the sewer extension limits requires many changes in the institutional and engineering aspects of wastewater control and management.

The evaluation of the water quality studies shows that approximately 75% of all streams have some degree of pollution. Some areas show periodic pollution while others, such as Cobbler Brook in Merrimac is grossly polluted.

Most streams flowing through populated areas have higher than normal nitrates and chlorides concentrations. Natural background streams located in sparsely settled areas have nitrate concentrations below 1 and chlorides below 10. These figures range upward as the population density increases.

Water quality studies conducted at municipal and private sewage treatment facilities show that the majority of the plants discharge high fecal coliforms, as high as 3,000,000 at one location in Ashburnham.

Solid waste disposal sites monitored downstream from the site or at point sources of suspected pollution reveals the presence of high chloride, iron and manganese. Some solid waste sites are used to dump septage (septic tank sludges), for example at Salisbury, Mass. Where such sites exist, flies, mosquitoes, gulls, starlings and blackbirds are present in large numbers. A septage dumping site in Acton covers many acres of open lagoons. Visits to the site found millions of mosquitoes breeding in the sludges and liquids within the lagoons. Many solid waste sites are or have been located in the groundwater table or along streams. A new sanitary landfill in Westminster discharges leachates to a stream. Refuse is dumped into the groundwater table. The site is located in glacial till.

Water supplies both surface and groundwater, are being encroached upon by housing developments, industries and highways. It is evident that the continuation of such practices will rapidly decrease the water quality of both our surface and groundwater supplies.

In addition to chlorination or ozonation, most surface supplies will require complete treatment involving coagulation, sedimentation and carbon filtration in the near future, unless the watersheds are better protected.

Many public water supply watersheds are becoming increasingly polluted as showed by the water quality studies in this report. Failure to maintain adequate disinfection could result in an outbreak of one of the enteric diseases.

Vermont and New Hampshire have experienced outbreaks of a parasitic infection of giardiasis. The parasite is not readily killed by the normal chlorine concentrations use to disinfect water. The source of the outbreak in Vermont was traced to improperly disposed of sewage from an individual land system.

Stormwater discharges containing sanitary wastes will continue to show its degrading influence on the main river water quality. Storm water discharges will increase feeder stream organic, nutrient and chloride loads.

It is felt that many of the shellfish beds will remain closed due to the periodic stormwater discharges and the increased feeder stream pollution discharging to the Merrimack.

The land disposal concept of municipal wastewater cannot be universally considered. Land disposal sites are limited as to the percolation qualities of the soil, groundwater depths and movement, topography and distance, and lack of proper ion exchange rates. These requirements have not been met in many cases where small dwellings and apartments land systems have been installed but failures occur.

Large land disposal systems should be considered in small communities having local sewage problems and where the flows are between .5 and 5 mgd, or in areas where a municipal wastewater treatment plant effluent would have adverse effects on the downstream water use, such as swimming, irrigation or water supply.

Successful land systems have been in operation for over 30 years at Fort Devens, Massachusetts and Lake George, New York. Sufficient depth of good percolating soil, such as sands and gravel; sufficient area for dispersion of applied sewage effluent; and soil chemical analysis are essential.

Recommendations for On-Lot Land Disposal Systems

1. Research should be funded for the development of new design criteria for on-lot waste disposal land systems, which will reduce the number of system failures and increase the operational life of a system to 20-25 years.

2. A stricter sanitary code should be established including research findings and recommendations.

3. Stronger enforcement of the sanitary code by Federal and State authorities should be implemented immediately.

4. Conduct a study to determine the effect on groundwater yields if all on-lot systems were abandoned and municipal collection systems installed in communities using groundwater as a drinking water supply. Studies should also include location of recharge areas and the feasibility of recharging these areas with AWT effluent.

5. Septage sludge treatment research should be funded to provide the best disposal methods, which will eliminate all public health hazards. Until this research is completed sludge from septic tanks should be treated at a municipal treatment plant wherever possible.

6. Local Boards of Health should not have jurisdiction over sewage disposal. There should be a Federal-State Authority.

Recommendations for Sewage Treatment Facilities and Collection Systems

1. Conduct extensive infiltration studies prior to design during the wettest period of the year. Testing for infiltration and exfiltration should be conducted throughout the construction of the collection system by the design engineer.

2. Sewage pumping stations should include standby pumps, emergency power supply and holding tanks or holding lagoons to eliminate all by-passes into adjacent streams, ponds or reservoirs.

3. Sewage treatment facilities should have dual equipment and standby electric power generation capacity to insure normal plant operation and complete treatment of all wastewaters being discharged.

4. Sewage ordinances must be adopted prior to plant operation to control all substances, which could upset the treatment plant, from entering the collection system. Pre-treatment requirements necessary to meet this ordinance must be strictly enforced, especially at industries where batch discharges or toxic discharges occur.

5. Long ranges evaluation studies should be conducted on the effectiveness and ultimate cost of various disinfection methods, including but not limited to chlorination, irradiation, and ozonation.

Recommendations for Solid Waste Disposal Sites

1. Before sites are approved, the area should be surveyed to determine groundwater elevations, and types of soil including impervious stratas. Ground water elevations and run-off should be observed during the wettest part of the year.

2. Operational procedures should be reviewed by Federal-State authorities to insure adherences to elevations and approved areas.

3. Existing dump sites that are creating pollution problems should be closed and the problem corrected before continuing its use.

4. Old or new dumps located in streams, runoff areas or in the groundwater table should be removed and the area restored.

5. Groundwater studies should be conducted around existing dumps to determine the extent of contamination.

6. Recycling efforts should be emphasized and support at the local, state and federal level.

Recommendations for Highway Construction

1. Stormwater discharges from newly constructed highways should not discharge directly to a water body.

2. Super highways should bypass public water supply watersheds wherever possible. The long range water quality should be given priority.

3. All run-off during highway construction should be contained to allow maximum settling before being discharged.

4. Road salting should be avoided adjacent to reservoirs, streams and ponds. In areas where drainage flows directly into a water body control application of road salting should be implemented.

L. Impact Assessment of Wastewater Management Alternatives in Terms of Public Health

In assessing the alternatives,* there are some general impacts which apply to most of the alternatives and these will be discussed first. The unique localized conditions can, then, be discussed.

Alternatives 1 through 4 deal with AWT as the end process. This complies with the 1985 goal of zero discharge of pollutants. AWT will remove substances that can interfere with disinfection of the wastewater, hence the bacterial count in the effluent is lower than that in the effluent from a secondary treatment plant. Chlorination, however, does not remove all the viruses that are present in wastewater so a health hazard may still exist. Organic matter, phosphorus and nitrogen concentrations are all reduced after advanced wastewater treatment. This results in higher dissolved oxygen levels in the receiving water, fewer algae blooms and a decrease in nuisance or septic conditions. The water is, therefore, more suitable for aquatic life and results in a well distributed population of species including higher order life and an ecologically sound environment suitable for recreation and water supply.

The degree of regionalization of a system has some pros and cons which must be weighed before a decision is made. Longer interceptors joining towns to a regional treatment plant cross areas that would remain untouched with individual treatment plants. Contamination of groundwater and streams in these areas can be possible from leaking pipes, overflows from overloaded systems and bypasses during lift station failures.

A large treatment facility tends to produce a more constant quality effluent since the operation and maintenance is better organized with full-time personnel, which is well supervised and a large maintenance department, including tools and qualified repair workers. Smaller treatment plants sometimes cannot afford to maintain an adequately trained staff or install automatic equipment for operation and maintenance and hence the effluent quality may vary considerably. The one advantage to a smaller plant is during failure of the system the volume of contaminated effluent is smaller in relation to the stream flow than a similar failure at a larger treatment plant.

Land application of treated effluent has a number of advantages. First, the soil acts as a buffer, in case of plant failure, contaminated effluent is not discharged directly into a recreational water or a water supply. Secondly, the effluent will eventually reach the groundwater and acts as a recharge supply. This is important in areas that depend on groundwater as their source of drinking water. In all land disposal sites, the area should be carefully evaluated to insure that the soil can accept and completely treat the total volume of wastewater disposed.

* See Appendix III for design and technical description of the alternatives.

The disadvantages of land application include possible groundwater contamination and large undeveloped land areas needed for disposal sites. Contamination is very important when the groundwater is used or is being considered as a drinking water supply. Large land areas are usually not available in urban areas and hence the wastewater has to be pumped to a site outside the collection system. However, rural areas have land available and find land disposal a practicable alternative.

Northern Middlesex Area Commission

Pepperell

The possible reuse of effluent from an advanced wastewater treatment facility at Pepperell by the local industries could conserve the town's limited groundwater supply. This is one advantage of Alternative 1. Alternatives 2, 3, and 4, involve pumping the wastewater from Pepperell to Ayer for further treatment. Alternative 2 poses less public health problems since the waste receives secondary treatment including chlorination before being pumped to Ayer.

Dunstable, Westford

These towns are to be served primarily by on-lot disposal until sewerage is needed. The proper design and installation of on-lot systems and land-use control can extend or even eliminate the need for a sewer system. Land-use control must include limiting development to places that have sufficient land to adequately dispose of all wastewaters created as a result of the development. This could mean development only on large lots and limited subdivision development.

There are sections of Westford that need central sewage systems to correct problems that exist in nearby streams. These areas are localized sections of towns that can be sewered with the wastewater either directed to a treatment plant at North Chelmsford (Alt. 1), Lowell (Alt. 2), or Billerica (Alt. 3 & 4); or treated in Westford followed by spray irrigation in Westford (Alt. 5). Alternative 1 would require the shortest transmission lines of the first four alternatives. Alternative 5 would be acceptable in terms of public health but the available disposal site is questionable; a separate treatment plant may create more hazards than joining another system.

Tyngsboro

Major pollution problems exist in this town and current plans are to install a sewerage system in east Tyngsboro with treatment of this waste at Lowell. West Tyngsboro should also be given immediate attention to alleviate the potential health hazard. Collection of this area's waste and treatment at a plant in North Chelmsford would create the least health hazard since it has the shortest transmission line and the interceptors would not cross the Merrimack River.

Chelmsford

A large treatment plant at Billerica including the total wastewater from the Town of Chelmsford could cause health hazards in the Concord River due to the large volume of effluent compared to the flow in the river, especially at low flow periods.

An AWT plant in North Chelmsford would eliminate the long interceptor lines to Lowell and reduce the public health hazards.

The use of a section of Tyngsboro for rapid infiltration in Alternative 5 has merits. However, any site in Tyngsboro that has sand and gravel should first be examined for a possible source of groundwater supply, since, there is need for additional supply to meet the increasing water demands of the Town of Tyngsboro.

Lowell, Dracut, Tewksbury

All five alternatives for Dracut require all wastewater to be delivered to a treatment plant in Lowell. Dracut is close enough to Lowell to minimize the hazards of overflows and infiltration problems. The collection of sewage from Dracut will greatly improve the water quality of Beaver Brook now heavily polluted by sewage overflows from Collinsville.

Tewksbury will also be served by a town collection system with treatment of this wastewater to be performed at a regional plant in Lowell in all five alternatives.

The location of the Lowell Treatment Plant is of some concern in regards to potential flooding.

The Fort Devens land disposal site to treat 24 mgd is questionable as to the soil's ability to handle this volume of wastewater. A pilot plant of about 2-3 mgd should be constructed and evaluated before acceptance of this alternative is final. The extent of the aquifers that feed the five groundwater supplies for Ayer and Fort Devens is unknown. The direction of groundwater movement, the location of water storage and recharge areas, and the depth to the water table plus detailed soil logs must be known in order to avoid nitrate contamination to a concentration that may create a health problem. Rapid infiltration that would result in a base flow discharge to the Nashua River of some 20-30 mgd of highly treated wastewater would decidedly improve the downstream water quality and limit the health hazards associated with recreation and water supply.

Billerica

The alternatives get more regionalized as they progress from 1 to 4. The larger facilities include longer interceptors and greater potential health hazards. In Alternative 2, the effluent is discharged to the Merrimack River. The large volume of wastewater that will be treated at a regional plant would be less of a health hazard if discharged into the Merrimack River versus the Concord River. In Alternative 3, the effluent would be discharged to the headwaters of the Concord River. This large wastewater volume would augment the flow in the river but could cause a health hazard since the intake for the Billerica water treatment plant would be downstream from the sewage treatment plant outfall. However, with the more decentralized Alternative 1, the effluent from Billerica AWT plant would be discharged into the Concord River below the water treatment plant, and would benefit the river during low flow periods.

Alternative 5 includes a rapid infiltration site in Concord - Carlisle for 7-12 mgd of secondary treated wastewater. Carlisle's only source of water is private wells. The discharge of sewage effluent to this area would, therefore, require a complete evaluation before use.

Merrimack Valley Planning Commission

Lawrence, Methuen, Andover, No. Andover

These four towns have grouped together to form the Greater Lawrence Sanitary District. This district is constructing a secondary treatment plant in North Andover to treat the wastewater from these four towns.

Alternatives 1 & 2 include wastewater from the Town of Boxford and Alternatives 3 & 4 include the effluent from the secondary treatment plant in Haverhill. Pumping the large wastewater volume from Haverhill to the GLSD could cause more health hazards than separate AWT facilities. The addition of the wastewater from Boxford does not present any adverse health problems.

Haverhill & Groveland

Alternatives 1 and 2 would upgrade the secondary treatment plant at Haverhill and result in better effluent to the Merrimack River. Alternatives 3 and 4 create more of a health hazard due to the pumping of the waste to North Andover and the total effluent entering the Merrimack at a single point. The land Alternatives 5 and 6 offer the greatest protection to the downstream public use of the Merrimack River provided that the rapid infiltration site can handle the hydraulic load.

Merrimac, Amesbury, Newburyport, Salisbury

Land disposal for each of these towns would be the best alternative in terms of public health, if acceptable disposal sites were available.

The small volume of flow favors land disposal. Separate secondary treatment plants and disposal sites located within each town would minimize the hazards associated with long transmission lines. The rapid infiltration sites in the Salisbury area are questionable in regard to the soil and water table levels. A single ocean outfall from the Newburyport plant may be the second best approach if land disposal sites are not acceptable. An estuary outfall would effect recreation and shellfish production more than an ocean outfall. The ocean outfall may have some short term negative effects during construction. Since Newbury is tied into the Newburyport primary treatment plant, it is included with the Newburyport alternatives.

Georgetown, Rowley, Boxford and West Newbury

These towns will remain on on-lot disposal systems. With proper control and land use management, this method of disposal can eliminate the need for sewers. However, it may be necessary to form a regional health or engineering district with strong codes, inspection and enforcement to insure the proper installation and operation of these systems.

M. Impact Assessment of the Recommended Plan

Northern Middlesex Area Commission

The land sites in Pepperell selected for effluent application will require considerable site investigation before a final approval of such sites can be made.

Throughout the commission region, a general problem exists of pumping stations, force mains, and gravity lines located in swamps, along brooks and in potential flooding areas. Protection of the adjacent waters from pollution must be provided by the construction of holding tanks or water-tight lagoons at each pumping station to hold at least a 24-hour maximum design flow to each station. Gravity lines and manholes along streams will pose a threat to downstream water users unless designs and elevations of manhole covers are based on maximum water quality protection.

The interceptor line along Beaver Brook will be periodically subjected to flooding which will greatly increase the flow at the Lowell Treatment Plant. The present gravity line in Dracut opposite water quality Station 32-A passes near or through a private or community well.

The discharge into the Concord River at North Billerica remains of concern considering the 7-day 10-year flow is about 25 cfs whereas the projected effluent discharge is estimated at 50 cfs.

Pipe alignments through swamps and near or within the hydraulic influence of water wells possess a potential health hazard. Back-up systems, holding tanks, water-tight pipe joints and elevations of manholes and pipe inverts in relation to maximum groundwater elevations are required for protection of the public health. To date, investigation within the Merrimack Basin show the need for better designs, construction and inspection of all phases in the development of a sewerage system. Wet weather flows remain a major problem in the reduction of plant efficiency because flows exceed design including chlorine concentration and detention.

Merrimack Valley Planning Commission

The proposed land disposal sites in Merrimac and Amesbury cannot be properly evaluated due to lack of detailed engineering data including soils, soil profiles, groundwater elevations and direction of flow. The area loadings of 3-11 mgd require much more extensive engineering and evaluation than is presently available for review.

Within this commission area, there remain the continued local water pollution and public health hazards from the location of pumping stations near surface water supplies where periodic pump failures would result in overflows and pollution to the water supply.

The location of the 200-acre land application site in Amesbury west of the Salisbury groundwater supply will require detailed soil and aquifer evaluation before serious consideration can be given to ultimate disposal there.

The high metal content of the Newburyport effluent discharging to the estuary is a serious set-back to the opening of the clam beds. The land disposal site in Salisbury may well prove to be too low in elevation for effective effluent subsurface flow. As in all land sites detailed, engineering studies must be made and evaluated before serious consideration can be given to the site.

Towns wishing to remain on individual on-lot disposal systems must strengthen their codes including design of systems, location, inspection, operation, maintenance and enforcement. The present codes, policies and enforcement will not prevent the necessity for public sewers.

It is doubtful that individual sewerage disposal can be administered at the local level much longer. Single and multi-family disposal systems in the future will require greater expertise in the review, approval, inspection and control than is presently available. Health hazards through surface and groundwater contamination will increase in these towns without guidance and institutional changes necessary at a regional, district or basin level.

Pumping stations, location, at brooks, reservoirs and sewer lines following streams have their built in pollution hazards and will always pose as a public health hazard to clean stream users. Overflows, infiltration, exfiltration, flooding, over topping manholes create a chain of events resulting in period pollution and sewage treatment inefficiencies.

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ADDENDUM to
APPENDIX IV - D

MERRIMACK RIVER BASIN STUDY

PUBLIC HEALTH SIGNIFICANCE

OF EXISTING WATER QUALITY AND WASTEWATER DISPOSAL PRACTICE

AND RECOMMENDED WASTEWATER MANAGEMENT

ADDENDUM

Table of Content

I. POTENTIAL HAZARDS OF WASTEWATER TO THE PUBLIC HEALTH

A. Biological Hazards

Wastewater is a potential carrier of many human pathogens. These disease causing agents can be divided into four groups: bacteria, parasites, viruses, and fungi.

1. Hazards in Effluents and Sludge

a. Bacteria

Bacteria are unicellular plants, some of which are potential pathogens to man. Many bacteria have the ability to live in the outside world, and synthesize their own food, however, others must take their nourishment from the bodies of living hosts, sometimes at the cost of injury to the host. As opposed to viruses, discussed later in this section, bacteria usually live outside the host's cells. Many bacteria are found in the feces of man, and therefore, are potential hazards in wastewater, sludges, and contaminated lakes and streams. A few of these known waterborne bacterial pathogens will be mentioned here, although numerous others may exist in a contaminated water environment.

Salmonella

Numerous serotypes of Salmonella are pathogenic to both animals and man. The commonest clinical manifestations of this disease are acute gastroenteritis with diarrhea and abdominal pains, although, occasionally the clinical course is that of enteric (intestinal) disease or septicemia (infection of the blood stream.) The most frequent mode of transmission is through food or water supplies contaminated by infected feces of man and animals. In 1966, a severe epidemic of Salmonella typhimurium diarrhea, affecting over 15,000 cases, occurred in Riverside, California, where the source of contamination was an unchlorinated public groundwater supply. (1) Salmonella typhi, the causative agent of typhoid fever, is infectious only to man. Typhoid fever is a serious disease characterized by fever, loss of appetite, slow pulse, involvement of lymphoid tissue, enlargement of the spleen, and, usually, constipation. (1) Its occurrence in the United States is rare. However, the largest waterborne outbreak of typhoid in this country since the 1930's occurred in early 1973 at the South Dade Labor Camp in Homestead, Florida, affecting 213 of the camp's 1900 inhabitants. The camp was served by a well that had been intermittently contaminated over the years, and, although the water was chlorinated, controls were found to be unsatisfactory. "Operating records revealed that unchlorinated water was distributed prior to the outbreak, and fecal contamination was documented in the wells and distribution system." (2) Six-hundred and twenty-eight cases of typhoid fever were reported to the U. S. Public Health Service Center for Disease Control in 1973.

Shigella

Shigellas cause intestinal disturbances ranging from very mild diarrhea to severe dysentary with intense inflammation and ulceration of the large bowel. Two-thirds of the cases of Shigellosis occur in children under 10 years of age; and in the United States, the disease is moderately endemic in lower socioeconomic areas, on Indian reservations, and in institutions (1). The disease is transmitted by person-to-person contact, contaminated food, and poor quality drinking water. Craun and McCabe, (2) in their "Summary of Water-borne-Disease Outbreaks in the U.S. during 1971 and 1972", report 6 water-borne outbreaks of Shigellosis resulting in 617 cases.

Leptospira

Leptospira are "coiled-shaped, actively motile bacteria that gain access to the blood stream through abrasions and mucous membranes" (3) causing fever, headache, chills, vomiting, muscular aches, and conjunctivitis (1). In severe cases, the kidneys, liver, and central nervous system may be affected. Most outbreaks occur among swimmers exposed to water contaminated by the urine of domestic or wild animals, although the disease may also be transmitted by direct contact with infected animals or ingestion of contaminated water. (1) Thirty-nine cases of this disease were reported to the U. S. Public Health Service Center for Disease Control in 1973.

Vibrio cholera

Vibrio cholera is the causative agent of cholera, a serious, acute intestinal disease characterized by sudden onset, watery diarrhea, dehydration, acidosis, and circulatory collapse. Untreated case fatality rate may exceed 50%. The disease is most often transmitted through ingestion of water contaminated with feces of infected persons, or food contaminated by polluted water, soiled hands, or flies. (1) In the 19th century, cholera was widespread; however, in this century, epidemics are largely confined to Asia.

Pastuerella tularensis

Tularemia, a disease characterized by chills, fever, prostration, and swollen lymph nodes (1), is caused by the bacteria, Pastuerella tularensis. The disease often infects wild animals, and the most common modes of transmission are the handling of contaminated wild animals and drinking water contaminated with urine, feces, and dead bodies of infected animals. One hundred and fifty-seven cases of this disease were reported to the U. S. Public Health Service Center for Disease Control in 1973.

Mycobacterium tuberculosis

Mycobacterium tuberculosis is the causative agent of tuberculosis, a pulmonary disease with symptoms of cough, fatigue, fever, weight loss, and chest pain, which are sometimes absent until advance stages. (1) Incidence of the disease is decreasing in the United States; the incidence of new cases was 30,937 in 1973. It is usually transmitted through contact with the sputum of an infected person or by the airborne route. The first documented waterborne case of human infection, reported in 1947, involved three children who fell into a heavily polluted river, 600 feet below a sewage discharge coming from a sanitarium (3). Since then, other cases involving near drowning of children in sewage contaminated water have been reported. Skin infections caused by mycobacteria in bathing waters have also been reported.

Coliform Bacteria

Standard methods (4) define the coliform group as including "all of the aerobic and facultative anaerobic gram-negative, nonspore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C". All organisms in this group may be found in raw sewage, although many may also be found in natural habitats.

The sub-group Escherichia coli has been found to be a characteristic inhabitant of the intestines of warm-blooded animals, and therefore a better indicator of fecal pollution (5). Various serotypes of Escherichia coli can cause gastroenteritis, characterized by profuse watery diarrhea, nausea, prostration, and dehydration (1). This disease agent, commonly causes diarrhea in infants and children under 2 years of age, and is also found to be the cause of diarrhea and urinary infections in adults (3). Enteropathogenic E. coli are present in streams and lakes polluted with feces of warm-blooded animals, and are, therefore, threats to people using these waters as water supplies or bathing areas. The survival time of Escherichia coli is shorter than some coliform subgroups, and it is less resistant to chlorine disinfection. For this reason, the total coliform group is preferred as an indicator of pollution, and ineffective water treatment methods.

Fair and Geyer (6) list the following criteria for a good indicator organism.

(1) "It must be a reliable measure of the potential presence of specific contaminating organisms both in natural waters and waters that have been subjected to treatment. To meet this requirement, the indicator organism or organisms must react to the natural aquatic environment and to treatment processes, including disinfection, in the same way, relatively, as do the contaminating organisms."

(2) "It must be present in numbers that are relatively much larger than those of the contaminating organism whose potential presence it is to indicate. Otherwise the presence of the contaminating organism itself would serve a more directly useful purpose."

(3) "It must be readily identified by relatively simple procedures."

(4) "It must lend itself to numerical evaluation as well as qualitative identification, since a knowledge of the degree of contamination is an essential interest and responsibility of the engineer."

The coliform group does meet most of the criteria listed. It is present in large numbers in contaminated water; it can readily and inexpensively be identified; and it does lend itself to numeric evaluation by statistical estimate with the Most Probable Number, (MPN) technique, or by direct count with the Membrane Filter (MF) technique.

However, it is questionable whether it meets the first of these criteria. Many studies have shown that coliforms do not react to the natural aquatic environment and treatment processes in the same way as viruses. It has been found that viruses generally survive longer, and are more resistant to many forms of water treatment that kill nearly 100% of the bacteria. The total coliform count has particular questionable value for application to renovated wastewater for potable use as it cannot indicate potential hazards of all disease organisms. It is also of limited use in testing bathing water, since more than one-half of all illnesses contracted from swimming water is not intestinal, but nasopharyngeal, in character. (7)

Simpler and more effective techniques need to be developed for detection of other disease entities, especially viruses, before they can become accepted indicators of pollution.

Many organisms mentioned in this section on bacteria are able to survive many days in polluted water. The best conditions for long survival are low temperature, low population of bacterial competitors, and quantities of nutrient-rich waste. (3) Under the right conditions, these bacteria can be carried many miles in a river to contaminate other areas. Many species of fish can also act as carriers of pathogenic bacteria to unpolluted waters. (3)

b. Parasites

Parasitism is defined as a symbiotic relationship in which one animal, the host, is to some degree injured through the activities of another animal. These animal parasites of man may be unicellular (protozoa) or multicellular (such as flatworms, flukes, or roundworms). Protozoa can be distinguished from bacteria, which are also unicellular, due to their larger size (between 10-200 microns) and their more intricate structure. Parasites of man are also found in human feces, and therefore a potential threat in wastewater and sludge.

(1) Protozoa

Cysts of Entamoeba histolytica, a pathogenic protozoan, are often found in wastewater and sludge, as they are quite resistant to many adverse conditions in their environment. Entamoeba histolytica is the causative agent of amebiasis, a disease of the large intestine. Symptoms range from mild abdominal discomfort to acute dysentary. If not treated, the infection may spread to produce abscesses of the liver, lung, brain, or ulceration of the skin (1). The disease is most prevalent in rural and low income areas. Its usual mode of transmission is by contaminated water containing cysts from the feces of infected persons (1).

Giardia lamblia is a pathogenic flagella that invades the small bowel causing symptoms ranging from mild diarrhea and abdominal pains to steatorrhea (fat maladsorption), anemia, and fatigue (1). The disease is more prevalent in the areas of poor sanitation, where it is transmitted by water contaminated by feces containing cysts of the parasite. Just recently there was an outbreak of 67 cases of this disease in a small town in Vermont due to contamination of a water supply with a septic tank overflow.

Craun and McCabe (2) reported 4 outbreaks of this disease resulting in 409 cases in the years 1971-1972.

Another extremely dangerous protozoan parasite found in wastewater in Naegleria gruberi, an amoeboflagellate that is the causative agent of primary amebic meningoencephalitis (1). Most cases of this disease occur in the summer months when persons who swim in contaminated water acquire the infection through the nasal cavity (8). The clinical course of the disease is quite dramatic, leading to neurological involvement and often death within 3 to 6 days (8).

(2) Multicellular parasites

Parasitic worms are a special threat to sewage treatment plant operators, farm laborers involved in irrigation agriculture, and to people swimming in lakes polluted by sewage or runoff from feedlots (3).

Ingestion of the larvae of beef or pork tapeworm, Taenia saginata or Taenia solium, through eating inadequately cooked beef or pork, can cause taeniasis. The larval stages of these parasites attach to the intestinal mucosa in man and develop into adult tapeworms, causing abdominal pain and indigestion (8). The animals themselves may become infected by ingesting eggs attached to plants grown in spray irrigated field or on land disposal sites. Humans may also become infected with the eggs of these tapeworms by ingestion of contaminated food and water (1). These eggs hatch in the small intestine of man and the larval forms, or cysticerci, migrate through the body and develop in the subcutaneous tissues and striated muscles. Blindness or motor and sensory disturbances may result when the larvae develop in the eyes or central nervous system (1). Incidence of this disease in the United States is usually less than one percent (3).

Ascaris lumbricoides is a roundworm that can infect the large intestine of man. It is usually found in tropical and temperate climates in areas of poor sanitation, (1) where infection is acquired through ingestion of contaminated food or water contaminated with eggs of the worm. The ingested eggs undergo migration through the body before returning to the stomach to grow to adulthood (8). Small number of worms may cause no symptoms; large numbers may cause digestive disturbances, pain, vomitting, and bowel obstruction due to migration of the worms to appendix, liver or peritoneal cavity (1). These worms may be a great hazard in sludge disposal.

Many other potentially hazardous parasites are found in wastewater and sludges, however, they are rarely found in this section of the United States.

c. Viruses

Viruses are the smallest pathogenic organisms known to man. In contrast to bacteria, they are incapable of multiplying outside the living cell. It has been hypothesized that viruses have evolved from bacteria through genetic mutation to the "summit or parasitism," losing all powers to synthesize their own nutrients (9).

They are capable of life only if furnished with the enzymic mechanisms, nutritive resources, and source of energy of some particular plant or animal.

Viruses have no cell structure, nucleus, cytoplasm, nor cell wall. They are composed of two parts:

1. A singular linear molecule of RNA (acids found in the cell nucleus, carriers of the genetic code). This molecule constitutes the core, and is the active, disease specific, host specific, genetic, infective part of the virus (9).

2. A protein sheath coating, called a capsid--the purpose of this coat is solely to protect the core (9).

Viruses are extremely small, ranging from 30 to 300 millimicrons (one micron is only 1/25,000th of an inch), and can exist in many forms of symmetry, the most common being cubic. The core of the virus can easily become separated from its protein coat, and thus be made vulnerable to RNA digesting enzymes. However, when the virus loses its coat, it loses only its infectivity, not its genetic and reproductive properties. The virus core may also regain its coat and assume its former infective properties (9).

The mechanism by which a virus is taken into the cell is still relatively unknown. Some have been found to enter the cell by a process known as pinocytosis, or engulfment by the cell (9). Another mechanism by which a virus may enter the host cell is demonstrated by bacteriophage (bacterial viruses); the phage particle comes in contact with a bacterial cell that has receptor sites with a certain physiochemical specificity. If the physiochemical structure of the virus particle corresponds to that of the receptor site of the bacterial cell, the virus is adsorbed on the cell wall. The bacteriophage makes an opening in the cell wall and releases its RNA inside the bacterial cell. Once inside the cell, the viral core breaks down the cell DNA and synthesizes the viral RNA from its genetic code. Thus, new infective viruses are formed which finally burst the cell and circulate to infect new cells (9).

There are over 100 different species of viruses known to infect humans by the waterborne route. This grouping of human viruses, which consists mainly of those which multiply in the gastrointestinal tract of man, includes the infectious hepatitis virus, enteroviruses (poliovirus, conxsackie virus, and echovirus), adenoviruses and reoviruses (3). Large quantities of these viruses are found in human feces and therefore in sewage, sewage effluents, and polluted rivers and streams. Viruses of plant, animal, and bacterial origin also abound in these waters, although little is known of their importance to humans.

The viral content of sewage is small compared to its bacterial content. Shuval, in a broad study of viruses in sewage recovered from five plaque forming units (PFU) to over 11,000 PFU per liter in sewage from the same city (10). (A plaque-forming unit is a measure of one virus particle growing on laboratory media). Studies by Geldeich et al calculate the <u>coliform</u> density in human feces to be 13 x 10^6/gram (11) other studies have estimated the viral concentration of feces to be 200 virus unit/gram. This gives a virus to coliform density ratio of 15 viruses to every million coliforms. Shuval's study in Israel found the ratio to be 1:1,000,000 (10). However, Berg estimates that, due to imperfection of techniques for viral detection, the amounts of viruses in sewage and river water exceeds by at least two orders of magnitude the amount detected (12).

The importance of viruses does not reside in numbers, but in infectivity. It is felt that the smallest quantities of virus that can be detected in susceptible cells in laboratory cultures (one plaque-forming unit) are sufficient to produce infection in man (13). The total effect of viruses are not easily detected as many times small amounts produce infection but not disease. Infection occurs when the virus enters the cell and multiplies. Overt disease occurs when there is sufficient cell damage to cause systemic malfunction (malfunction of a specific body system). Danger lies in the fact that an infected person with no disease symptoms can excrete large numbers of viruses, thus causing his contacts to become infected or to get the disease. The medical field estimates that for each person who visits a physician with identifiable viral symptoms, 100 to 1,000 other people are infected, posing threats as carriers (14).

Many viral disease outbreaks are accounted for by the term gastroenteritis. Gastroenteritis (inflammation of the stomach) is a symptom of a disease that may be caused by bacteria, chemicals, or viruses. Since it is not required that this disease be reported to health authorities, it can only be estimated that the number of viral cases occurring per year is in the hundred thousands many of them being waterborne (14).

Virus transmission by the water route is best demonstrated by the virus causing infectious hepatitis, a disease of the liver. From 1895 to 1964, there were at least 50 outbreaks of infectious hepatitis attributable to contaminated water (3). The largest waterborne epidemic of this disease occurred in Delhi, India during the years 1955 and 1956. The epidemic, caused by a contaminated municipal water supply, involved over 27,000 clinical cases, and an estimated ten times this number in subclinical cases (3). Craun and McCabe reported 11 waterborne outbreaks of the disease in the United States during 1971 and 1972, causing 266 cases (2). A total of 51,523 cases of infectious hepatitis were reported to the U. S. Public Health Service Center for Disease Control in 1973.

A list of potential waterborne viruses and their associated diseases and symptoms are given in Table 1.

Viruses may also have delayed effects. For example, they may be oncogenic (tumor producing) or teratogenic (inducing birth defects). The reported induction of cancer in mice by very small amounts of reovirus 3, a member of the group of viruses that are common to man and many animals, shows the importance of investigating the impact of nonhuman viruses on man (13).

TABLE I

The Huamn Enteric Viruses That Can Be Waterborne and Known Diseases Associated With These Viruses

Group	Subgroup	No. of Types or Subtypes	Disease Entities Associated With These Viruses	Pathologic Changes in Patients	Organs Where Virus Multiplies
Enterovirus	Poliovirus	3	Muscular paralysis	Destricution of motor neurons	Intestinal mucosa, spinal cord, brain stem
			Aseptic meningitis	Inflammation of meninges from virus	Meninges
			Febrile episode	Viremia and viral multiplication	Intestinal mucosa and lymph
	Echo virus	34	Aseptic meningitis	Same as above	Same as above
			Muscular paralysis	Same as above	Same as above
			Guillain-Barre's Syndrome*	Destruction of motor neurons	Spinal cord
			Exanthem	Dilation and rupture of blood vessels	Skin
			Respiratory diseases	Viral invasion of parenchy-miatous of respiratory tracts and secondary inflammatory responses	Respiratory tracts and lungs
			Diarrhea		
			Epidemic myalgia	Not well known	
			Pericarditis and myocarditis	Viral invasion of cells with secondary responses	Pericardial and myocardial tissue
			Hepatitis	Same as above	Liver parenchyma
	Coxsackie virus	>24	Herpangina†	Viral invasion of mucosa with secondary inflammatory responses	Mouth
			Acute lymphatic pharyngitis	Same as above	Lymph nodes and pharynx
	A		Aseptic meningitis	Same as above	Same as above
			Muscular paralysis	Same as above	Same as above
			Hand-foot-mouth disease‡	Viral invasion of cells of skin of hands and feet and mucosa of mouth	Skin of hands and feet and much of mouth
			Respiratory disease	Same as above	Same as above
			Infantile diarrhea	Viral invasion of cells of mucosa	Intestinal mucosa
			Hepatitis	Viral invasion of liver cells	Parenchyma cells of liver
			Pericarditis and myocarditis	Same as above	Same as above
	B	6	Pleurodynia§	Viral invasion of muscle cells	Intercostal muscles
			Aseptic meningitis	Same as above	Same as above
			Muscular paralysis	Same as above	Same as above
			Meningoencephalitis	Viral invasional invasion of cells	Meninges and brains
			Pericarditis, endocarditis, myocarditis	Same as above	Same as above
			Respiratory diseases	Same as above	Same as above
			Hepatitis or rash	Same as above	Same as above
			Spontaneous abortion	Viral invasion of vascular cells (?)	Placenta
			Insuin-dependent iabetes	Viral invasion of insulin producing cells	Langerhans' cells of pancreases
			Congenital heart anomalies	Viral invasion of muscle cells	Developing heart
Reo virus		6	Not well known	Not well known	
Adenovirus		31	Respiratory diseases	Same as above	Same as above
			Acute conjunctivitis	Viral invasion of cells and secondary inflammatory responses	Conjunctival cells and blood vessels
			Acute appendicitis	Viral invasion of mucosa cells	Appendia and lymph nodes
			Intussusception	Viral invasion of lymph nodes (?)	Intestinal lymph nodes (?)
			Sub acute thyroiditis	Viral invasion of parenchyma cells	Thyroid
			Sarcoma in hamsters	Transformation of cells	Muscle cells
Hepatitis		>2	Infectious hepatitis	Invasion of parenchyma cells	Liver
			Serum hepatitis	Invasion of parenchyma cells	Liver
			Down's Syndrome**	Invasion of cells	Frontal lobe of brain, muscle, bones

*Ascending type of muscular paralysis †Febric episode with sores in mouth ‡Rash and blisters on hand-foot-mouth with fever §Pleuritis type of pain with fever

**Mongolism

Another group of disease causing viruses, the "slow viruses," was not recognized until quite recently. These viruses are extremely small in size, and resistant to heat, ultraviolet radiation, formalin and freezing. They have an extremely long incubation period and lead to chronic degenerative disease. These viruses can persist unnoticed in the hosts cells for such a long time because they are able to replicate without causing death to the cell. It has been hypothesized that it may not be the virus, but the response of the body's immune system to infected cells that causes the most damage in these diseases (15).

A recent outbreak of multiple sclerosis, usually a disabling neuromuscular disorder, in the Town of Mansfield, Massachusetts, was a cause of much concern as it has been linked to a possible viral contamination of the town's waters between the years of 1932 and 1936 (16). Fourteen confirmed cases of this disease were found in Mansfield, a town with a population of 10,000, giving the town one of the highest multiple sclerosis rates in the nation. Nine of the fourteen people had grown up in the town, and eight had lived within a few blocks of each other near a pond that was heavily polluted during the years 1932 to 1936. It has been hypothesized that multiple sclerosis is a viral disease contacted at puberty but fails to show any symptoms until early adulthood or middle age. The mean age of the patients from Mansfield in 1934 was 14; this finding concurs with a study by Poskanzer et al (17) in which a mean age of 14 at time of exposure to the disease causing agent was calculated. Although this hypothesis cannot be confirmed, it does point out the great need for research in the characteristics of slow viruses and their mode of transmission.

Survival of viruses in the water environment is influenced by many factors. Generally, they have been found to survive longer at lower temperatures. Also, their survival has been found to be longer in treated or "clear" water or in grossly polluted water than in moderately polluted water (11). This is a contrast to bacteria which survive longer with an increasing degree of pollution. In most waters, viruses appear to last longer and are much more resistant to disinfection and other treatment processes than bacteria. A comparison of survival times of various viruses and bacteria at different temperatures is given in Table 2.

The survival of viruses in sea water may be shortened by a marine anti-viral agent or agents (MAVA). Shuval (10) has studied such agents, and found them to be biological in nature, heat labile, and ether sensitive. They appear to be very complex substances, and not much is known, as yet, of their mode of action.

d. Fungi

Fungi are non-photosynthetic plants that do not form embryo (seeds). They do not have physiologically differentiated or functional roots, stems, and leaves; they consist of one cell or aggregates of undifferentiated cells (9). Some fungi are etiological

TABLE 2

Effect of Storage: Laboratory Study Demonstrating Days Required for 99.9% Reduction of Viruses and Bacteria in Sewage (11)

	No. of Days		
	Temperature°C		
Organism	4°	20°	28°
Poliovirus 1	110	23	17
Echovirus 7	130	41	28
Echovirus 12	60	32	20
Coxsackievirus A9	12	..	6
Aerobacter aerogenes	56	21	10
Escherichia Coli	48	20	12
Streptococcus faccalis	48	26	14

agents of deep-seated and superficial mycoses (fungal infections) in man. They are often found in natural habitats such as soil, and more recently they have been detected in sewage and polluted waters. Cooke and Kabler (18), in a study of sewage effluents, sludges, and polluted waters in southwestern Ohio, reported three pathogenic fungi--Allescheria boydii, Aspergillus fumigatus, and Geotrichum candidum--to occur consistently. Both A. fumigatus and G. candidum are etiological agents of pulmonary diseases common to man, while A. boydii has been found to cause fungal tumors. Of the three, G. candidum was most frequently isolated.

2. Hazards in Air-Aerosols

Aerosols are defined as particles ranging from .01 to 50 μ suspended in air (19). Aerosols are another potential hazard of wastewater when they are generated from sewage treatment units and spray irrigation systems as they may contain organisms that are harmful to man. Aerosols that range for two to five μ in size never reach the lungs because they are captured in the upper respiratory tract. Here they are removed by the action of cilia and pass to the digestive tract via the pharynx. (20) If aerosols of this size contain gastrointestinal pathogens, infection may result. Respiratory infections may result from smaller aerosols containing respiratory pathogens. Deposition on the aveoli of the lung is greatest for particles in the one to two μ size range, and then decreases to a minimum at approximately .25 μ. Below .25 μ, aveolar deposition increases again (21).

Bacterial pathogens in aerosols have a fairly rapid die-off rate due to dessication in flight. Evaporation rate is directly related to high temperatures and low relative humidity. Studies of evaporation rates show that a 50μ water droplet will evaporate in .31 seconds in air with 50 per cent relative humidity and a temperature of 22°C (22). Evaporation rate is also affected by the presence of chemical additives. Chemical additives may decrease the rate of water evaporation and thus provide a longer survival time for pathogens (23). Different bacteria have different survival times. E. coli has been shown to have a short life span in the aerosol form while coliforms of the genus Klebsiella, which are pathogens of the respiratory tract, survive much longer as they form a large capsule which protects them from dessication (24).

Both activated sludge and trickling filter units emit considerable numbers of pathogenic particles. Napolitano and Rowe (25) found that activated sludge units emit ten times more coliforms than high rate trickling filters. In activated sludge units, the aeration tanks were found to be the most prolific in discharging bacteria as significant amounts of coliforms were found at a distance of 150 feet from the aeration tanks with winds varying from 220 to 405 ft/min. Besides temperature and humidity, these studies found that coliform concentration in the air also depended on size of the source, velocity of the wind, and ultraviolet radiation from the sun.

As for spray irrigation sites, Sepp describes a German study where downwind travel of aerosols increased 85 feet for every 2.25 MPH increase in wind velocity (26). In another study, it was found that with a five to 10 MPH wind, the mist zone extended 105 feet downwind from a sprinkler with a spray radius of 30 feet (26). Because of differences in wind speed, buffer zones of 50 to 200 feet around spray irrigation sites are recommended. Droplet travel may also depend on the spray equipment. High pressure, high trajectory, fine droplets travel further. Aerosol travel may also be decreased by pointing spray nozzles downward and utilizing forested sites that maximize entrapment of droplets (27).

3. Hazards to the Food Chain

Pathogens present in water polluted by sewage may be taken up by aquatic organisms. Shellfish, in feeding, will filter 10 to 20 gallons of water per day through their systems. Shellfish are known to be carriers of bacterial disease agents, and in the past many outbreaks of typhoid fever have been attributed to contaminated shellfish. They may also be carriers of viral disease; in fact, 1,700 cases of infectious hepatitis resulting from contaminated shellfish have been reported. Most studies on virus uptake in shellfish have found that most of the common species do concentrate and retain significant amounts of virus, and that, when contaminated shellfish are transferred to clean seawater, the rate of elimination of viruses is considerable in all cases.

Liu et al (28) studied the uptake of poliovirus 1 by the Northern Quahaug and found virus contamination to occur quite rapidly. Most of the viruses appeared to be concentrated in the digestive diverticulum where they were not adsorbed onto, nor did they penetrate, the cells. It was also found that shellfish cleanse themselves quite rapidly when placed in a unit of clean, flowing seawater. Under these conditions, virus concentrations were reduced to a non-detectable level within 48 to 96 hours. Metcalf and Stiles (29), studying shellfish in a New Hampshire estuary found virus survival in oysters to depend on temperature, pollution level, and species of virus. Low temperature caused longer survival; in fact, survival appeared to be indefinite below 4°C. Survival was also longer at high pollution levels due to the presence of nutrients. Finally, of the three viruses studied, the poliovirus, coxsackievirus, and echovirus, survival of the coxsackie virus was longest and poliovirus was shortest under the same set of conditions. It was hypothesized from data collected in the study, that virus transmission by shellfish would be optimal when high pollution levels and maximum survival times coincide. In the New Hampshire estuary, highest viral pollution of shellfish occurred from July to October, and lower water temperatures, which are conducive to longer virus survival, occurred in the early fall. The data predict an increased probability for virus transmission via consumption of raw shellfish beginning in midsummer and peaking in early fall. This prediction recapitulates the seasonal pattern described for shellfish-induced epidemics of infectious hepatitis in man.

4. Disease Vectors and Nuisance Organisms

Control of disease vectors and nuisances is a major concern in the managment of water resources. Unsanitary conditions created by improper management of wastewater often lead to situations conducive to the breeding of vectors.

A vector is an animal which can transmit a communicable disease from an infected person to a well person. In New England, the vector of major concern is the Aedes mosquito, a potential transmitter of the Eastern encephalitis virus to man and horses. Of lesser concern are the Anopheles mosquito, a potential vector of malaria, and the American dog tick, a potential vector of Rocky Mountain Spotted Fever. (124)

Two species of mosquitoes known to transmit Eastern encephalitis to man, Aedes solicitans and Aedes vexans, are commonly found in New England. Aedes solicitans breeds in brackish pools in salt marshes along the Atlantic coast from Maine to Florida, while Aedes vexans breeds in inland areas along the flood plains of rivers on the muddy edges of receding pools. Both mosquitoes are fierce day-biters and have quite long flight ranges (5-20 miles) (125).

The Eastern encephalitis virus, which may be carried by these mosquitoes, can cause a severe and frequently fatal encephalitis in man and equines (horses). In man, the disease is usually characterized by a sudden onset with high fever, vomitting, drowsiness or coma, and severe convulsions. In severe cases, death occurs 3 to 5 days from onset. Survivors are often left with mental retardation, convulsions, and paralysis (1).

The virus was first identified from the brain of horses in 1933, and was identified as the agent causing an epidemic of man in Massachusetts in 1938-39. In the 1939 epidemic, thirty-four cases with 25 deaths were reported, and six out of the nine survivors were left with permanent brain damage (125).

Recent research in the vectors of Eastern encephalitis indicates that birds are the common reservoirs (or carriers) of the virus. The infection chain is normally limited to birds, small mammals, and mosquitoes, with an occasional spill over to horses and humans. The bog or swamp mosquito, Culiseta melanura is the primary vector in the bird-mosquito-bird chain, and rarely bites man, while mosquitoes of the Aedes species transmit the virus to horses and humans. In Massachusetts, only the fresh water swamp mosquito Aedes vexans has been found to transmit the virus. Outbreaks are usually attributed to heavy rainfall, and high temperatures, which cause exceptionally large mosquito populations (124). However, a recent outbreak in Southeastern Massachusetts in August and September 1974 was not preceded by the usual chain of events leading to an Eastern encephalitis outbreak. The Regional Office of the Department of Public Health in Lakeville, which tests mosquito pools in the summer months for the encephalitis virus, could not isolate the virus from the man-biting Aedes mosquito. Only the vectors in the bird-mosquito-bird chain, Culiseta melanura, appeared to be infected. Also, there was less rainfall in this section of Massachusetts than there was in previous years. However, there was a large population of Culiseta mosquitoes as this mosquito can overwinter in its larval form, and heavy rainfall in the previous year had lead to a large overwintering population (126).

Three cases of the virus were reported to the Massachusetts Department of Public Health (one in Taunton, one in Foxborough, one in Middleborough) during the summer of 1974. One death was reported as of September 1974.

Mosquitoes and other insects may also create great annoyance problems for man. The domestic mosquito Culex pipiens breeds in urban areas in streams, street catch basins and clogged drainage ditches containing water of high organic content. Numbers of this mosquito have increased over recent years due to the increase of polluted water in urban areas (124). This mosquito is not an aggressive biter; however, it invades houses, and its persistant high-pitched hum continued late into the night makes it a considerable pest (125).

Horseflies and deerflies are another nuisance problem in eastern Massachusetts. These flies inhabit marsh areas, creating severe annoyance at recreational and work sites, as their bites create fairly deep, painful wounds causing considerable flow of blood (125).

Biting midges are a nuisance in coastal resort areas, freshwater inlets, and tidal pools. Non-biting midges, also create problems. They breed in brackish water, tidal creeks, and freshwater ponds. Usually high organic concentrations in the water will favor production (124). Swarms of these insects have interfered with human activities and comfort, and have even caused traffic hazards when crossing highways (125).

It is predicted that vector and nuisance problems will increase in the future due to the rapid increase in population, the development of suburban areas close to breeding plans, the expanded use of recreation areas, inadequate control of wetlands, concern over pesticide use, and the development of insect resistance to various pesticides. To combat this growing problem, research surveillance and technical assistance must be provided in problem areas, along with an increase in size, number, and scope of mosquito control programs with more emphasis on water management and source reduction.

In Massachusetts, encephalitis surveillance is handled by the Lakeville Regional Office of Public Health. The State Reclamation Board has the responsibility for supervision of all organized mosquito control and nuisance control projects.

B. Chemical Hazards

1. Hazards in Effluents and Sludges

Chemical agents found in wastewater may pose a threat to the public health as they can contaminate water supplies and become concentrated in man's food supply. Some chemicals may be present in such quantities that they create acute toxic effects when ingested while others accumulate in the body in small quanitites over a long period of time producing long-term chronic disease. Small concentrations of chemicals, such as trace metals, may never produce overt disease but do cause such subclinical effects as fatigue, headache and nervousness that are never brought to the attention of a physician or never linked to chemical toxicity.

A substance is considered toxic "if it impairs growth, reproduction, or metabolism of an organism when supplied above a certain concentration" (30). Even elements essential to life may be toxic above certain concentrations. Animals have the ability to eliminate and detoxify many chemical toxins entering the body. Schroeder states that "toxic action occurs only when homeostatic mechanisms for excretion are overcome" (31).

Toxic substances of great concern in wastewater are the heavy metals, cyanides, nitrates, pesticides, organic compounds and radioactive substances.

a. Heavy Metals

Heavy metals are some of the most dangerous elements in our environment. Rapid increase of industrialization has caused the release of these elements into the environment in enormous amounts. "The last half century has demonstrated all too clearly that biological adaptive processes are too slow to cope with the environmental change induced by technology." (32) Although much is known about the toxic effects of large doses of heavy metals, less is known about the effects of long-term small doses on biological systems, food chains, and humans.

Many metals, when present in small quantities, are essential to life. Schroeder lists 14 "good" metals (33). Four that are needed in bulk quantities are: sodium, magnesium, potassium, and calcium. Ten that are needed in very small quantities are: vanadium, chromium, manganese, iron, cobalt, copper, zinc, selenium, strontium, and molybdenum. Metals are "bad" when they accumulate with age and are present in quantities greater than what is necessary for life and health. There is no cellular requirement at all for some metals such as lead and mercury. Certain metals may also react with others to cause synergistic effects (caused when the danger from two combined pollutants is greater than the sum of individual dangers). Such is the case with arsenic and lead, which when present together, have increased toxic effects (34).

Many of these potentially toxic metals are discussed below:

<u>Mercury</u>

For a long time, large concentrations of mercury have been known to produce acute toxic effects. Inorganic mercurials used in industry were known to produce a disease called "hatters madness," which was common in the felt handling trade due to the use of mercuric nitrates in the felt making process. Industrial control of mercury came early, although these controls applied only to inorganic mercury and large doses. The danger of organic mercurials, such as methyl mercury, which are far more toxic than inorganic mercurials, was not recognized until recently. The main inpetus for research into the toxicity of organic mercury arose from a severe outbreak of mercury poisoning in Minimata, Japan, during the 1950's. Minimata, a coastal town with a population of 10,000, experienced an outbreak of a strange disease causing loss of coordination, numbness of limbs, blindness, and loss of hearing. Forty-three people died and 68 were left permanently disabled (32). One-third of these cases appeared in infants born to undiseased mothers. In such cases, the disease was expecially severe, causing deformity, mental retardation, lack of muscular control, and early death. Extensive investigations found mercury to be the culprit. Fish and shellfish played a major role in the diets of the inhabitants of this coastal town. Concentrations of mercury in the effluents from factories which used mercuric sulfate as a catalyst in synthesizing acetaldehyde and discharged to the ocean were extremely high in inorganic mercury content. Investigators were baffled since even these high concentrations of <u>inorganic</u> mercury were not known to produce toxic effects, and furthermore, fish and shellfish in the area were found to contain 1 - 3 ppm and 5 - 20 ppm <u>organic</u> mercury (wet weight). It was later found that inorganic mercury can become methylated to form organic mercury by microbial action in anaerobic conditions, and that organic mercury is readily accumulated in the bodies of animals.

Organic mercury is more toxic than inorganic mercury because of its chemistry (32). It accumulates in humans because it can become firmly bound to various proteins and fats which make up the cells of the body. Because it is so tightly bound, its half-life (length of time needed for a system to rid itself of half the substance absorbed) is much longer. Organic mercury can concentrate in the liver, kidney, and brain; and it has a different half-life in each of these different organisms. The half-life in the brain and fetus is particularly long even though they have slow rates of uptake. This explains the devastating effect organic mercury has on the nervous system and on new born children. Organic mercury also has an extremely serious effect on the nervous system because we are endowed with a limited number of brain cells at birth. These cells and the neural pathways connecting them do not have the ability to reporduce or repair themselves. When damage is done to these cells and pathways of the brain, it is usually irreversible. In addition, extensive damage must occur before effects can be seen because many neural pathways are not absolutely necessary for a function to be carried out, but merely duplicate other pathways in case of breakdown. Thus, a large number of people in Minimata may have suffered a great amount of brain damage through destruction of these duplicate neural pathways without clinical symptoms. Children may be more sensitive to the toxic effects of mercury because they have fewer neural pathways thus leaving themselves open to more widespread damage.

Mercury can also cause genetic damage as it has been known to cause chromosome division at concentrations as low as .05 ppm (35).

Mercury enters the environment through the burning of natural fuels, the extraction and use of mercury itself in mining, smelting, and refining, the manufacture of chemicals and paper, and its use as a fungicide in agriculture. Many feel that mercury is a problem only in fresh water and not in the ocean because it can become greatly dispersed in large volumes of ocean water. However, "hot spots" may be created in ocean water because mercury becomes firmly bound to the sediments, and when methylated, it is rapidly taken in by organisms. Mercury can become a great problem in estuaries and fresh water. In 1970, fish in Lake St. Clair and the St. Clair River on the Canadian border were found to contain as much as 7.8 ppm mercury (35). Scientists in Sweden found that the mercury concentration in pike, which is at the top of the aquatic food chain, ranged up to 17 ppm in the skin (36).

Many estimates have been made as to the threshold level for mercury poisoning in man. Scientists at the Oak Ridge National Laboratory, using a safety factor of 10, set the allowable daily intake at about 100 micrograms/day (37). The present USPHS

Drinking Water Standards has no limit for mercury, and the new proposed Drinking Water Standards set the maximum acceptable concentration for raw water used for drinking water at 2 ppb. The Swedish standard is .03 mg/day (30 micrograms/day) assuming two meals of fish a week (39). The FDA interim standard for mercury is .5 ppm for fish and .2 ppm for shellfish. To set a definite threshold value, further research is needed in the mechanisms of mercury toxicity in man.

Lead

Lead is another dangerous heavy metal, that like mercury, has no useful function in the human body. Lead is also similar to mercury in other aspects as it is more potent in its organic forms, it has a more devastating effect on infants and children and it can cross the placental barrier and damage the fetus. Lead poisoning may be either acute or chronic, although the latter is most common. Early symptoms of chronic lead poisoning are listlessness, anemia, abdominal pain, and vomitting. Chronic lead poisoning can eventually lead to extensive liver and kidney damage, peripheral nerve disease, permanent brain damage and genetic damage (38, 39, 40).

The normal blood lead level in humans ranges from 15 to 40 μg Pb/100 ml of blood (33). The threshold blood lead level for lead poisoning is not known. Some researchers have placed the threshold level as high as .7 ppm to .8 ppm (70-80 μg/100 ml), while other researchers in Great Britain have calculated the safe threshold level for children to be .36 ppm (41). Levels of lead as low as .20 ppm blood have been shown to inhibit the enzymes necessary for the biosynthesis of heme (which combines with a protein to form hemoglobin) (42).

Lead accumulates in the body with age in the bone and sometimes the aorta (31). The normal human intake of lead has been estimated to be .3 mg/day, and the average person can excrete .5 mg/day. However, if lead levels in the environment are above normal, a person may easily accumulate small quantities over a period of time. This accumulated lead may become dangerous as "under conditions of high calcium metabolism, such as feverish illness of cortisone therapy, lead may be mobilized, and a toxic amount is released from the skeleton" (39). Schroeder believes that innate lead toxicity is common among city dwellers causing tiredness, nervousness, apathy and lack of ambition (33).

Major sources of lead are food and the atmosphere. Lead from the atmosphere may enter the water environment from atmospheric fallout from motor vehicles and industry. Drinking water may also be contaminated with lead from lead piping especially in areas where there is soft, acidic water to dissolve the lead. The present WHO and USPHS limit for lead in drinking water is .05 ppm, assuming most people drink two liters/day (5).

Cadmium

Cadmium is another heavy metal that may reach toxic amounts in water. Acute cadmium poisoning may cause gastroenteritis.

Long-term exposure to small doses may cause chronic disease with first symptoms of tiredness, shortness of breath, an impaired sense of smell, and painful joints, and later symptoms of decalcification of the skeleton, bone fractures, and kidney malfunction accompained by excessive excretion of proteins, amino acids, glucose, and calcium (43). A classic outbreak of this disease occurred in Japan along the Jintsu River in Toyama Prefecture. From World War II to the 1960's, over 200 cases of this disease (called "itai-itai" because of the patient's shrieks of "itai-itai", as they suffered severe pain in their bones) were reported. The water from the Jintsu River, which was contaminated with cadmium, lead, and zinc from nearby mining tips, was used to irrigate rice crops and was also used by many as a source of water supply. Kobayashi made a study of this disease outbreak and found that cadmium, lead, and zinc were not only present in high concentrations in the water but also in the irrigated rice. He then studied the effects of these three metals on rats, and found that cadmium alone caused symptoms characteristic of the disease (43).

Cadmium is accumulated with great efficiency in the kidneys and liver and to a lesser extent in the pancreas, spleen, thyroid, adrenals, gall bladder and testes (44,45). In mammals, cadmium becomes bound in the kidney as a metalloprotein and is released very slowly. From an average daily intake of 200-500 ug of cadmium, the average person retains 1.8 to 3.6 ug (44). It has been found that the cadmium concentration in man's kidney increases until approximately age 50 (44). Cadmium has been implicated in hypertensive disease. Schroeder found that extremely low doses of cadmium (only a few hundred micrograms), when injected into the blood stream of small animals, produce increased blood pressure (46). In another study, Schroeder created a cadmium-free environment for animals, and then found that the addition of five micrograms/l cadmium to the drinking water of a portion of these animals caused a shortened life span, thickening of the small arteries of the kidney, hardening of the arteries, enlargement of the heart, high blood pressure, and high cadmium concentration in both the kidneys and blood vessels (47). These findings duplicate the findings in high blood pressure of humans. A study around the world showed that people dying of hypertension had more cadmium in their kidneys and a higher cadmium/zinc ratio than people dying of other causes (47).

Cadmium has also been found to be associated with kidney damage, cirrhosis of the liver, and damage to the lungs. Many studies have indicated that cadmium is a carcinogen. Experiments on animals have shown cadmium to cause damage to the central nervous system (48). Cadmium may also cause destruction to the testicles and placenta (48).

The maximum allowable limit for cadmium in raw water used for drinking water supplies is .01 mg/l. This value is exceeded in many cities due to soft water and galvanized pipes (zinc ore contains cadmium) (49). Soft water has the ability to dissolve metals in pipes and has been linked to cardiovascular disease. It has been hypothesized that it is not soft water, but the metals, such as cadmium dissolved by soft water, that are related to cariovascular disease (47). Large amounts of cadmium are released into the environment each year from processing and refining of cadmium bearing ores, the incineration of cadmium containing products, the eletroplating industry, the battery industry, and the use of phosphate fertilizers mined from deposits with sedimentary bands of fossiled fish teeth (which contain a lot of cadmium) (49). Cadmium may also enter the food chain of man by becoming concentrated in plants and shellfish.

Arsenic

Ingestion of as little as 100 mg of arsenic can cause severe poisoning (5). Chronic poisoning with arsenic is more common, as arsenic is easily absorbed from the gastrointestinal tract and lungs and becomes distributed throughout the blood and tissues, inhibiting enzymes needed for cellular oxidation (50). Arsenic is mildly toxic in its pentavelent (+5) oxidation state and highly toxic in its trivalent (+3) oxidation state. Arsenic, like mercury, may become methylated in the water environment; however, while organic arsenic in the air is highly toxic, organic arsenic concentrated in fish from water is of low toxicity. Also, although aquatic organisms concentrate arsenic from water, it is not progressively concentrated along the food chain (50). Many arsenic compounds have been implicated as being carcinogenic to humans; however, experimental results do not support this hypothesis (51).

Arsenic may react with other metals in the environment. It may decrease the toxic effect of selenium, but it increases the toxic effect of lead. Arsenic enters the environment through natural processes through the burning of fossil fuels, the mining and processing of sulfide minerals, the increased erosion of the land, and to a much lesser extent, through the use of phosphate detergents and fertilizers (50). The new proposed national drinking water standards set the maximum allowable concentration of arsenic in drinking water supplies at 1.0 mg/l.

<u>Chromium</u>

Ingestion of chromic acid and hexavalent salts of chromium, in large amounts, can cause irritation of the gastrointestinal tract with vomitting and diarrhea; and chromic acid may be irritating to the skin (51). In most of its soluble forms, however, the toxicity of chromium is quite low. Inhaled hexavalent chromium has been shown to be carcinogenic, and chromate ore roasts and a few selected chromium compounds have induced malignant tumors in subcutaneous and muscle tissue when implanted at certain sites in rats and mice (52). However, no carcinogenic effects from ingested chromium have been found. Because not enough is known about chromium and its compounds to set threshold limits for human toxicity, present drinking water standards are set at .05 mg/l to insure protection of the public health (2). Schroeder and others have shown that chromium is an essential micronutrient effecting growth and survival (53). Chromium has been found to be a protective agent against lead toxicity in rats (54). Concentrations of less than 5 - 8 ppb indicate a deficiency state in humans, as low states of chromium in the body may impair glucose tolerance (53). Chromium salts may enter the water environment from tanning and plating industry wastes and from industries producing paints, dyes, ceramics, and paper.

<u>Copper</u>

Copper is only moderately toxic to humans. Ingestion of large amounts (above 50 ppm) of copper salts causes vomitting, gastric pain, dizziness, cramps, convulsions, and sometimes death (55). Concentrations in water are ususally too low to cause these symptoms. There is no evidence of chronic copper poisoning as it does not accumulate in the body. However, if emesis does not occur when large amounts are ingested, systemic copper poisoning may result causing damage to the capillaries, liver, kidney and central nervous system (55). Copper is used in the metallurgical, elec= troplating, pesticide, electrical, textile, munitions, and photographic industries (62).

Small amounts of copper in drinking water may be beneficial, as copper is an essential micronutrient. The recommended limit in water used for drinking purposes is 2 mg/l (5).

<u>Selenium</u>

Selenium is toxic to man in certain forms; however, the most toxic selenium compounds are found in the air environment.

Water and soil may become contaminated with selenium through industrial fallout. Selenium compounds have been known to cause depression, nervousness, gastrointestinal disturbances, and garlic odor of the breath and sweat (56). Selenium in small amounts may also be capable of increasing dental caries if consumed during tooth development (57). Despite these harmful effects, trace amounts of selenium may be necessary in the diet. It has been found that chicks receiving diets inadequate in selenium suffer severe malfunction of the pancreas, a breakdown in the digestion of dietary fats, and a breakdown in vitamin E adsorption (58).

There appears to be conflicting findings on the carcinogenicity of selenium (52). Selenium may have an inhibitory affect on cancer development, as studies have found that sodium selenide reduces the number of artifically-induced tumors in mice (59). Other studies have found an inverse relation between sodium selenide in soil and forage crops and human cancer rates and an inverse relation between human blood levels of selenium and human cancer rates (60). The receommended limit for selenium in water used for drinking is .01 mg/l (5).

Antimony

Antimony, in low concentrations, has been known to shorten the life span in small mammals (61), and may have quite damaging effects on the heart and liver (62). No detailed studies have been done on the long-term effects of antimony, although it is quite widely used in industry and in the manufacture of paints, textiles, rubber, and ceramic glazes.

Sodium

Sodium is an essential nutrient to all animals, and deficiency of this substance produces primarily a failure to grow and survive. Much attention has been given to sodium lately as it has been linked with the development of high blood pressure. In studies where rats have been fed high concentrations of sodium salt, some researchers have found a relationship between high sodium diets and high blood pressure, while others have found the occurrence of high blood pressure to be herediatry (63). Sodium has also been implicated in cardiovascular disease. Water softened by sodium cycle ion-exchange resins is high in sodium, and soft water has been found to be directly related to cardiovascular disease. However, sodium is also often found in waters with high mineral content (hard waters), which are inversely related to cardiovascular disease. The conflicting relationships between sodium concentrations and water hardness indicate the need for further research on the subject. Because sodium does have a beneficial effect on man in concentrations normally found in water, and sodium concentrations in food are often much higher than the sodium concentrations of water, there is no limit set for the amount of sodium in drinking water.

Other Trace Metals

Limits for boron, iron, manganese, and zinc have been set in drinking water. However, these limits are not based on potential threat to public health (and in some cases, these elements in drinking water are quite beneficial to man), but on their threat to plants and wildlife, and on the taste and corrosion problems they are likely to create.

b. Nitrogen compounds

Nitrogen is essential to all living things, although in some forms, and at certain concentrations, it presents a hazard to the health of both man and animals. In recent years, there has been a marked increase in the nitrogen concentration of both surface and groundwaters in the United States due to increased municipal and industrial waste discharge (both effluents and sludge), septic tank discharge, and runoff from dumps and animal feedlots. Non-point sources such as runoff, leaching, and tile drainage from agricultrual, urban, and other lands also play an important role in the increased nitrogen content of our waters (64).

Humans are being exposed to large amounts of nitrogen in both their food and water. Vegetables, such as beets, spinach, and brocolli accumulate large quantities of nitrate due to increased application of fertilizers; meat may also be high in nitrates due to a nitrate-nitrite preservative widely used in the meat-processing industry (64). Present drinking water standards set the limit for nitrogen as nitrate (NO_3) at 45 mg/l (5). Most surface water supplies in the United States comply with this limit, however, many groundwater supplies in rural areas do not, due to agricultural contamination (64). Thus, nitrates are of great concern in considering wastewater reuse by recharge to an aquifer.

Excessive concentrations of nitrates and nitrites in humans can lead to a condition call methemoglobinemia. Ingested nitrites and nitrates (which can be converted to nitrites by the human intestinal bacteria) can convert the hemoglobin of the blood to methemoglobin. Hemoglobin is the oxygen carrying component of blood, which when converted by nitrites to methemoglobin, loses its ability to combine with oxygen. Cyanosis (bluish tinge to the skin) and disturbances of bodily functions due to lack of oxygen may occur when five to ten per cent of the total hemoglobin has been converted to methemoglobin. Since 1944, over 2,000 cases of this disease have been reported (49). Most cases occur in infants under three months of age because (64):

1. Fetal hemoglobin is more readily converted to methemoglobin.

2. Infants are deficient in two enzymes necessary to convert methemoglobin to hemoglobin.

3. Infants have a high fluid intake per body weight.

4. The stomach of an infant is at a lower pH, which is more conducive to growth of bacteria which convert nitrates to nitrite.

5. Gastrointestinal illness in infants permits bacteria responsible for nitrate conversion to nitrite to move higher in the gastrointestinal tract.

Many subclinical cases of nitrate poisoning must exist. A study of Pethukov and Ivanov showed a slowing of conditioned motor reflexes in response to auditory and visual stimuli in children whose water contained only 26 mg/l nitrogen as nitrate (66).

Nitrosamines, formed from reactions between nitrates, nitrites, and various amines, are known to produce acute toxic effects as well as carcinogenic, teratogenic, and mutagenic (producing chromosomal aberrations) effects. It is known that nitrosamines may be formed in processed foods, however, further research is needed to determine whether they can be formed in water, and in man, after ingestion of food and water containing nitrates and nitrites (64).

c. Hardness

Hardness in water is caused by the presence of cations of elements such as calcium and magnesium. Recently many studies have found hardness of water to be inversely proportional to cardiovascular disease. Schroeder et al, in a study of 163 cities in the United States, found that Ca^{++} and Mg^{++} correlate well with male death rates from coronary heart disease (67).

Most recently, a study in England compared men living in soft water towns to men living in hard water towns in terms of indicators of cardiovascular disease. Men in both groups were matched according to social class, occupation, and way of life. Men from soft water towns had higher blood pressure, plasma cholesterol, heart rate, and cardiovascular mortality rates than men in hard water towns. These differences could be important in explaining the difference in cardiovascular mortality between hard and soft water towns (68).

d. Cyanide

Small doses of cyanide (CN) may act as a respiratory stimulant, but at higher doses, it acts as a respiratory depressant. Large doses of cyanide may paralyze the central nervous system, and arrest respiratory movement and beating of the heart (55). The safe threshold of cyanide has been determined to be 19 mg/l (as CN), and doses over 50 - 60 mg may be fatal (5). Smaller doses of cyanide (5 - 10 mg) are detoxified mainly in the liver where it is converted by enzymes to thicocyanate (a non-toxic sulfur complex) (2). Detoxification mechanisms in humans are usually inexhaustable, although toxic effects do occur when the rate of cyanide adsorption surpasses the rate of detoxification. Chronic cyanide poisoning does not occur; however, prolonged administration can cause an undersupply of oxygen to the body's cells, destruction of nerve fiber casings, and changes in the thyroid (55). The proposed drinking water standards set a limit for cyanides in water used for drinking at .2 mg/l (5).

e. Pesticides

Pesticides are chemical agents used to kill unwanted species or pests. The increased production and use of these substances has been the cause of much concern in recent years, as in large quantities they have been proven highly toxic to man and wildlife; and at persistant low levels, they have been linked to cancer in man. Most of the pesticides used today are of the synthetic organic type; the two most popular types are the chlorinated hydrocarbons and organophosphates.

Chlorinated hydrocarbons such as DDT, dieldrin, aldrin and lindane eliminate pests through their action on the central nervous system (69). Unfortunately, they may effect the nervous system of other animals and man in high amounts and may have harmful chronic effects on vertebrates at low levels. Such effects include fatty infiltration of the heart, and fatty degeneration of the liver. Chlorinated hydrocarbons are dangerous for three basic reasons (70). First of all, they are nonspecific universal poisons, killing other species besides the pest. Secondly, they are not biodegradable, and can persist in the environment for long periods of time. Finally, they are able to concentrate in the fat of man and animals. This last point causes the biological magnification of these substances in the food chain. Animals occupying higher positions in the food chain have smaller populations yet these smaller populations are exposed to higher concentrations of pesticides in their food.

Fish and other aquatic animals and fish eating birds are especially sensitive to these substances. Many lakes and streams contain fish with DDT levels above 5 mg/kg, the alert level set by the Food and Drug Administration. Lake trout reproduction has been inhibited by DDT. Concentrations of 5 ppm in trout eggs have been known to kill fry when they adsorb their final yolk sac before hatching (71). Chlorinated hydrocarbons have also been proven to produce reproductive difficulties in birds by interfering with their ability to metabolize calcium. This interference decreases the thickness and weight of the eggshell, causing it to break (71). Many other effects on smaller animals are known, but not much is known of the effects of these pesticides on man. They have been indicated as carcinogens, but evidence is not conclusive. Man already contains high concentrations of these substances, and it is disturbing to note that an average mother's milk contains .05 - .26 ppm DDT (69). The FDA limit for DDT in milk is .05 ppm.

Organophosphates such as parathion, malathion and azodrin are more toxic than chlorinated hydrocarbons, but less stable and less persistent in the environment (69). These pesticides are cholinesterase inhibitors. They inhibit the enzyme responsible for the breakdown of nerve transmitter substances, causing acute activity of the nervous system and death. Because of their lack of persistence, these substances have not been indicated in chronic disease; in fact, mammals have enzymes that can break down malathion.

The LD_{50} (oral dose lethal to 50% of exposed laboratory animals in mg/kg) of various pesticides is given in Table 3 (72).

TABLE 3 (72)

TOXICITY OF THE MORE COMMON PESTICIDES AS SHOWN BY THEIR LD/50's in mg/kg

Organochlorine group

Aldrin	55
Benzene hexachloride	500
Chlordane	457
Dieldrin	60
Endrin	10 to 12
Heptachlor Epoxide	40 to 60
Methoxychlor	6000
DDD	8400
DDT	113
DDE	880
Diazinon	100 to 150
Lindane	125
Simazine	5000
2,4,5-T	100
2,4-D	560
Toxaphene	90
Atrazine	1750

Botanicals

Allethrin	680
Barthrin	680
Pyrethrins	820 to 2600
Ryania	1200
Rotenone	132
Sabadilla	4000
Warfarin	58 (F) 323 (M)

Organophosphorous group

Ethion	27 to 65
Guthion	16.4
Parathion	6 to 15
m Parathion	9 to 25
Malathion	1000 to 1375
Dibrom	430

Others

Fenuron	6400
Calcium cyanamid	42
Silvex	650
Carbaryl (Sevin)	540
Ferbam	7000

Pesticides enter the aquatic environment by direct application to surface water (as in the case of mosquito larvicides), water runoff, and particulate erosion from contaminated land. In metropolitan areas, these substances may be discharged through sewers to sewage treatment plants where they may impair treatment processes by sterilization of micro-organisms (71). Pesticides cannot be removed from water and wastewater by most treatment processes; activated carbon adsorption seems to be most effective. Care must be taken as their degradation products may be just as harmful, if not more harmful, than the pesticides themselves (71). In aquatic systems, pesticide concentrations decreases with time, as their concentrations increase in sediments and aquatic organisms. However, it may be possible that concentrations in sediments can recycle to the water phase. Pesticides usually don't reach the groundwater as they are readily adsorbed on soil particles when applied to the land, and are very difficult to leach out (71). The major mechanisms for their dissipitation in the environment are adsorption, degradation, volatilization, and plant uptake. New proposed limits for pesticides in drinking water are given in Table 4.

f. Organic Compounds

Other organic compounds are becoming increasingly present in the nation's waters. A report by A. D. Little for the Environmental Protection Agency in December 1970 (73) found 469

TABLE 4

RECOMMENDED LIMITS FOR CHLORINATED HYDROCARBON INSECTICIDES

Compound	Water Recommended 1/ limit (mg/l)
Aldrin	0.00000014
Chlordane	0.003
DDT	0.05
Dieldrin	0.00000014
Endrin	0.0002
Heptachlor	0.0001
Heptachlor Epoxide	0.0001
Lindane	0.005
Methoxychlor	1.0
Toxaphene	0.005

1/ Assume average daily intake of water for man - 2 liters.

reported or suspected organic chemicals in drinking water. Organics such as phenols, pyridine, diphenyl ether, kerosene, nitriles, PCB (polychlorinated biphenyls), and benzene derivatives are suspected carcinogens. While carcinogenic effects on animals have been experimentally proven, extrapolation of these results to humans is difficult and uncertain (74). The toxicity of the breakdown products of these chemicals must also be considered; and many of them may react together to produce synergistic effects (75). For example, benzyprene and certain detergents react together to produce cancer in animals; however, alone they do not. Methods of control of these substances are still in their infancy. Drinking water standards do not exist for many of them as these standards were developed for relatively clean protected water, not water heavily polluted by industry (75). Also, most conventional treatment methods are ineffective in removing such exotic wastes.

2. Hazards to the Food Chain

a. Trace Metals

Trace metals may be taken up by aquatic organisms living in waters polluted by industrial effluents. Trace metal concentrations in the marine bioshpere are higher than in the hydrosphere (30). It has been proven that these substances can become concentrated in mollusks up to many hundred times the level found in the marine environment. Several pathways of this concentration process have been suggested (78):

1. Particulate ingestion of suspended material
2. Ingestion through preconcentration in the food chain.
3. Complexing of metal by linkages with appropriate organic molecules.
4. Incorporation of metal ions into physiologically important systems of the mollusk.
5. Uptake by exchange, for example, onto the mucous sheets of the oyster.

Studying various species of estuarine mollusks, Pringle et al (30) measured the concentration levels, uptake rates, and depletion rates of selected trace metals under various conditions. Average trace metals levels in shellfish taken from 100 sampling stations along the Atlantic coast are given in Table 5. Trace metals accumulation by various species of shellfish in a simulated natural environment were also studied; these results are given in Table 6. It has been found that the food chain and sediments may contribute some metals, although most metals are taken up in their soluble phase from surrounding waters (79). Experimental results of this study indicated that accumulation rates depend on temperature, condition of the particular shellfish, pollution levels, and the physiological role the metal plays in the body of the shellfish (79). Pringle also found accumulation rate to be greatest in the soft-shell clam and least in the hard-shell clam. Depletion rates of different trace metals in shellfish were also measured; the results of these experiments are given in Table 7. Pringle found

TABLE 5

AVERAGE TRACE METAL LEVELS IN SHELLFISH TAKEN FROM ATLANTIC WATERS (30)

(Values are given in PPM Wet Weight)

Element	Eastern Oyster	Soft Shell Clam	Northern Quahaug
Zinc	1428	17	20.6
Copper	91.50	5.80	2.6
Manganese	4.30	6.70	5.8
Iron	67.00	405	30
Lead	.47	.70	.52
Cobalt	.10	.10	.20
Nickel	.19	.27	.24
Chromium	.40	.52	.31
Cadmium	3.10	.27	.19

TABLE 6

TRACE-METAL ACCUMULATION STUDIES IN A SIMULATED NATURAL ENVIRONMENTAL SYSTEM (30)

Environmental Level	Values mg./kg. Initial	Values mg./kg. Final	Total Accumulation	Accumulation Time in Days	Accumulation Rates (mg./kg./day)	Species	Sea Water Temperature
.1 ppm	23	79	56	10	5.60	Soft Shell	20^{o}C.
.2 ppm	15	85	70	25	3.00	Soft Shell (Toxic-poor condition)	20^{o}C.
.05 ppm	35	200	165	8	20	Soft Shell	No control (25-26^{o}C.)
.5 ppm	6.5	8	1.5	25	.06	Quahaug	No Control (10^{o}C.)
.2 ppm	10	27	17	50	.35	Soft Shell	20^{o}C.
.05 ppm	0	8 (3.8 in 4 wks)	8	70	.10	Soft Shell	20^{o}C.
.1 ppm	0	9 (6.5 in 4 wks)	9	56	.16	Soft Shell	20^{o}C.
.1 ppm	0	112	112	70	1.60	Soft Shell	20^{o}C.
.2 ppm	0	235	235	40	5.80	Soft Shell	20^{o}C.
.2 ppm	0	260 (220 in 70 days)	260	84	3.10	Soft Shell	20^{o}C.
.2 ppm	0	35	35	56	.63	Quahaug	20^{o}C.
.025 ppm	0	17	17	49	.35	Eastern Oyster	20^{o}C.
.05 ppm	0	35	35	49	.71	Eastern Oyster	20^{o}C.
.1 ppm	0	75	75	49	1.50	Eastern Oyster	20^{o}C.
.2 ppm	0	200	200	49	4.00	Eastern Oyster	20^{o}C.

TABLE 7

TRACE METAL DEPLETION STUDIES IN A CONTINUOUS FLOW SYSTEM
(30)

Species	Metal	Depletion Range, in milligrams per kilogram per day		Depletion Time, in days	Temperature, in degrees Celsius	Depletion Rate, in milligrams per kilogram per day	Source of Specimens
		initial	Final				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Soft Shell	Copper	124	30	7	20	12.50	from 0.1 ppm accumulation study
Soft Shell	Copper	96	34	11	20	5.10	River View (water off)
Soft Shell	Copper	68	9	10	20	5.90	Allens Harbor
Soft Shell	Copper	62	34	4	20	7.00	Long Meadow (water off)
Soft Shell	Copper	58	20	15	20	2.60	Jerusalem (water off)
Soft Shell	Copper	52	24	15	20	1.90	Aliens Harbor (water off)
Soft Shell	Copper	48	22	4	20	6.50	from 0.2 ppm accumulation study
Soft Shell	Copper	33	20	7	20	1.90	Charlestown
Hard Shell	Copper	17.5	13.0	84	no control (4-12)	0.05	Boston Harbor
Hard Shell	Manganese	21	16	84	no control (4-12)	0.095	Boston Harbor
Hard Shell	Zinc	38	26	84	no control (4-12)	0.12	Boston Harbor
Hard Shell	Iron	27	27	84	no control (4-12)	0.0	Boston Harbor
Oyster	Lead	203	188	21	20	0.71	from 0.2 ppm accumulation study
Oyster	Lead	79	63	21	20	0.76	from 0.1 ppm accumulation study
Oyster	Lead	32	22	21	20	0.46	from 0.05 ppm accumulation study
Oyster	Lead	24	5	21	20	0.91	from 0.025 ppm accumulation study

that these substances become chemically and structurally incorporated into the tissues of the various organs of the mollusk and essentially become an integral part of the animal. Thus, biological turnover, or depletion, depends on the reversal of the incorporation process. The depletion rates for metal contamination were found to be much slower than those for biological contamination. In general, depletion rates for each species were directly proportional to uptake rates, that is depletion was fastest in the soft-shell clam and slowest in the hard-shell clam. Depletion also seemed to depend on the initial concentration of the metal in the shellfish.

Although much information exists on accumulation and depletion of metals in shellfish, very little is known about these processes in fish and crustaceans. It is known that fish do accumulate metals but not to the degree found in mollusks. There is evidence that metals such as chromium and cadmium do not accumulate in the edible portion of the fish (80). Lobsters and crabs also take up metals, but again, in smaller quantities than shellfish (81). Higher accumulation rates in shellfish can be easily explained; they pump a large quantity of water through their bodies each day to strain out essential nutrients, and through this process, they also accumulate a lot of nonessential substances.

The National Shellfish Sanitation Program of the Food and Drug Administration has proposed alert levels for trace metals in shellfish (82). These levels were proposed for the sole purpose of acting as indicators of changes in trace metal concentrations in shellfish growing waters; they do not reflect levels dangerous to man, as not enough information exists on heavy metals toxicity in man. Alert levels for trace metals in shellfish are listed in Table 8.

b. Pesticides

Hundreds of millions of tons of pesticides are released into the environment each year due to agricultural practices, industrial discharges, and pest control. Large percentage of these substances eventually reach rivers and estuaries where they are taken up by marine organisms, such as fish and shellfish, that are used for food purposes. The Food and Drug Administration has not set levels for these substances in fish; however, the National Shellfish Sanitation Program has proposed alert levels (see Table 9) for pesticides in shellfish (82). The Program has further recommended that if combined values obtained for Aldrin, Dieldrin, Endrin, Heptachlor, and Heptachlor Epoxide exceed 0.20 ppm, such values be considered as alert levels which indicate the need for increased sampling until results indicate the levels are receding. It has also recommended that when the combined values for the five pesticides exceeds 0.25 ppm, the shellfish harvesting area should be closed until levels recede.

TABLE 8

PROPOSED ALERT LEVELS FOR TRACE METALS
IN SHELLFISH (ppm) (82)

Metal	Oyster	Quahaug	Soft Shell Clam
Hg	.2	.2	.2
Cd	3.5	.5	.5
Pb	2.0	4.0	5.0
Zn	2000	65	30
Cr	2.0	1.0	5.0
Cu	175	10	25

TABLE 9

PROPOSED ALERT LEVELS FOR (82)
PESTICIDES IN SHELLFISH (ppm)

Aldrin	.20
BHC	.20
Chlordane	.03
DDT) Any or all	
DDE not to	1.5
DDD) exceed	
Dieldrin	.20
Endrin	.20
Heptachlor	.20
Heptachlor Expoxide	.20
Lindane	.20
Methoxychlor	.20
2, 4-D	.50

II. EFFECTIVENESS OF WASTEWATER TREATMENT IN TERMS OF PUBLIC HEALTH

A. Water-Oriented Treatment

1. Removal of Biological Hazards

As wastewater is often discharged into the waters that are eventually used for recreation or a source of drinking water supply, it must receive adequate treatment to eliminate potentially pathogenic organisms. The various methods of wastewater treatment vary in their ability to effectively remove these pathogenic agents. In this discussion, emphasis will be placed on virus removal, as many viruses have been found to be more resistant to treatment processes than bacteria. Also, current disinfection practices, if carried out properly, may destroy nearly 100 percent of the bacteria in wastewater, while viral destruction may be considerably less. It must be remembered that only one virus unit is enough to cause infection or disease in man.

a. Primary Treatment

Primary treatment usually consists of screening and degritting to remove large particles and debris, and sedimentation to remove suspended solids. This treatment method is probably the most widely used, however, it is the least effective. Primary treatment, without disinfection, removes virtually no viruses at retention time of two to three hours, which is the design value used for most treatment plants (83).

b. Secondary Treatment

After primary treatment is used to remove solids by physical means, secondary treatment may be employed to remove organics biologically. Secondary treatment systems rely on biological cultures to convert the water soluble organics of primary treated effluents to water insoluble organics, carbon dioxide, water and energy. The two most common biological treatment processes are the trickling filter and the activated sludge process.

Trickling Filters

In the trickling filter system, primary effluent is sprayed on a bed of crushed rock or other media coated with biological slimes. These slimes consist of bacteria, protozoa, algae, and fungi which build up on the crushed media and break down organics in the wastewater. Kelley et al found virus removal by this system ineffective, as they found 70 percent of samples of trickling filter effluent to be positive for viruses (84). Shuval, in a series of tests with trickling filter effluents recovered 22 - 100 percent of the viruses present in influents (10). Trickling filters are not effective in virus removal because large organic compounds present in sewage are more readily adsorbed than smaller viruses. Also, even when viruses are adsorbed, they may later be replaced and leach out of the filter system (85).

Activated Sludge

Activated sludge treatment ususally consists of sedimentation followed by aeration in a basin with air diffusers or mechanical aerators to provide aeration and mixing. The mixture of wastewater and sludge is then pumped to another sedimentation basin where solids settle out. A portion of the sedimentation basin sludge, which accumulates a population of aerobic bacteria, is recycled to the aeration basins to be combined with incoming raw waste. The aerobic microorganisms in this sludge metabolize, biologically flocculate, and remove organic components of the wastewater.

Tests performed on wastewater in a continuous flow laboratory unit have shown that, at a retention time of approximately seven hours, 98 percent removal of coxsackie virus A9, and 90 percent removal of polio virus 1 may be achieved. Removal of coliforms and fecal streptococci under the same conditions exceeded 96 percent (86). Experiments performed in the absence of activated sludge seed have shown much lower virus removals (89), and experiments carried out in the absence of air have shown no virus removal at all (87). This indicates that the constituents of activated sludge as well as aeration are important factors influencing removal of viruses. Pathogen removal in this process is largely a physical process brought about by adsorption and sedimentation, although some studies indicate that some virus inactivation may occur due to antiviral substances (87). Thus, viruses are still active in the sludge and must be treated to eliminate their pathogenic potential.

Experiments in the field have shown lower virus removals indicating that this process requires further treatment to effectively eliminate public health hazards.

c. Disinfection

All treatment processes are usually followed by some form of disinfection. Disinfection is a form of specialized treatment for the destruction of harmful disease-producing organisms. The most common disinfectant in use is chlorine, although chemicals such as bromine, iodine, ozone, and treatment with ultra-violet radiation are effective. Efficiency of disinfection depends on many different factors such as the kind and concentration of organisms to be destroyed, the kind and concentration of disinfectant, contact time, the chemical and physical character of the water to be treated, and the availability of a quick, reliable method to test for residual disinfectant concentrations (88). In general, viruses and parasitic cysts are more difficult to destroy than bacteria. Existence of clumps of viruses may contribute to their resistance to disinfection (89). Disinfectants also vary in their mode of inactivation. Ozone and the halogens, such as chlorine, bromine, and iodine, inactivate bacteria by penetrating the cell wall and oxidizing essential cellular function units such as enzymes (89). Inactivation of viruses by these substances results from denaturation of the protein capsid leaving the nucleic acid core unaffected. Ultraviolet radiation is thought to kill viruses by the point heat effect. When an ultraviolet photon hits a RNA molecule in the virus, the temperature rise is enough to cause disruption of the molecule or part of the molecule (89).

Chlorination

Chlorine, when applied to water of low pH (below 6.0), hydrolyzes to form HOCl, hypochlorous acid, one of the fastes virucides known. In waters of higher pH, HOCl dissociates to form H+ and OCl^-. The hypochlorite ion, OCl^-, is also an effective disinfectant; however, it is 60 to 70 times slower than HOCl (90). Both HOCl and OCl^- in water are lumped under the term "free residual chlorine." However, the disinfecting potential of chlorine is usually greatly reduced, as most treatment plant effluents contain a large concentration of ammonia, and organic nitrogen compounds, which at high pH, combine with chlorine to form chloramines (termed as "combined chlorine"). Chloramines destroy bacteria at a rate up to 270 times slower than HOCl (90). Viruses are more difficult to destroy than bacteria. Although a chlorine residual of .5 mg/l for 15 minutes is commonly used for bacterial removal, chlorine residuals of 9 mg/l, for 15 minutes and 21 mg/l for 10 minutes, especially if the chlorine is in combined form, have been reported necessary to inactivate 90-99% viruses in secondary effluents (91,92).

Few studies have been done on disinfection of viruses in wastewater and it is impossible to set a fixed free chlorine concentration and contact time for inactivation of all viruses in all types of water. Liu's study of effects of chlorination on viruses in Potomac River water shows the wide range of resistances among different virus types to chlorine (Table 10) (93). The dosage-time

TABLE 10

RELATIVE RESISTANCE OF 16 HUMAN ENTERIC VIRUSES TO 0.5 mg/l FREE CHLORINE IN POTOMAC WATER (pH 7.8 & 2°C) (93)

Virus	Experimental Min. for 99.9% inactivation
Reo 1	2.7
3	$<$4.0
2	4.2
Adeno 3	$<$4.3
Cox A9	6.8
Echo 7	7.5
Cox B1	8.5
Adeno 7a	12.5
Polio 1	16.2
Echo 29	20.0
Adeno 12	23.5
Polio 3	30.0
Cox B3	35.0
B5	39.5
Polio 2	40.0
Echo 12	$>$60.0

combination depends on the virus destruction desired and the pH and temperature of the water (94). In general, it has been found that a rise in temperature of 10°C increases the destruction rate by 200-300 percent (90). Effective destruction of viruses also requires low ammonium ion and organic concentration of the water, low turbidity, and low virus concentration (94). Thus, other methods of treatment which commonly precede chlorination are quite necessary as not only do they reduce the virus concentrations, but they also remove substances that interfere with the disinfection process or protect the virus particles from contact with chlorine.

Chlorine does have its disadvantages. Large concentrations of chloramines in water are toxic to fish and other river life (85). Also, chlorine may react with residual organic compounds to form potentially hazardous chlorinated organics (75). The transport and handling of chlorine may also be a hazard to the public health, as it is poisonous to humans and fatal in gaseous form at levels above 1,000 ppm. Finally, chlorine is currently in short supply due to the high energy requirement for its manufacture.

Ozone

Ozone (O_3) is a powerful disinfectant that is manufactured by the action of strong electrostatic discharges in air, oxygen, or a mixture of both. A review of literature shows ozone may be more effective than chlorine in inactivating viruses and persistant parasitic cysts (95). Research shows that as the dose of ozone is increased, there is little improvement in the disinfecting ability until a critical dose is reached. However, when the critical dose is reached, ozone is virtually 100 percent effective, and an ozone residual appears. A reasonable dose for destruction of bacteria is 1.5 to 2 ppm (96).

As for viruses, Pavoni et al, showed that an ozone dosage of 15 mg/l and an ozone residual of .015 mg/l for five minutes killed 100 percent bacteria phage f_2 (bacterial virus) in secondary effluent (96). Bender states that an ozone residual of .5 mg/l for four to five minutes in the effluent from an advanced waste treatment plant will destroy 100 percent poliovirus 1 (97).

Ozone is less sensitive to temperature and pH than chlorine, and therefore more reliable than chlorine under varying water conditions. Also, it doesn't react with ammonia to form substances toxic to fish. Ozone, however, does have its disadvantages. Because it has such a short half-life in water, it does not leave any residual protection. Another disadvantage is that in heavily polluted waters, it may repture organic molecules into fragments that are more easily metabolized by microorganisms, thus promoting slime growth (92). Ozone, like chlorine, may be poisonous to humans. However, it must be generated on site, thus it does not present a transportation hazard. These disadvantages must be weighed against the fact that ozone, as opposed to chlorine, creates practically no secondary pollutants.

d. <u>Coagulation-Sedimentation</u>

Coagulants are added to water and wastewater to aggregate suspended solids so that they may be removed by settling. Suspended solids usually have a negative charge in water, and are attracted to the positive charge of the coagulant cation (such as the Ca^{++} in lime). This process has another benefit, as at higher pH values found in wastewater, viruses take on a negative charge and they may also be attracted to the cations of the coagulant. Usually coagulation is followed by flocculation, a process that aggregates coagulated particles together by agitation into a settleable mass called a "floc." In general, both bacterial and virus removal is a result of good floc formation which depends on adequate coagulant concentration, absence of interfering substances such as organic matter, high pH, and proper agitation (90). Virus removal results from the formation and settling of a coordination complex between the cation and carboxyl groups on the viral protein coat.

Chang et al (99) studied the effects of two-stage coagulation and flocculation on Ohio River water. A dosage of 25 mg/l alum or ferric chloride was used at each stage. The results of this study are given in Table 11. It can be seen from this table that virus removal parallels reduction of turbidity.

In another study by Chaudhuri and Engelbrecht (100), a dose of 40-50 mg/l alum in diluted wastewater removed 96-97 per-

TABLE 11

Direct of Flocculation: Laboratory Study on the Removal of Virus, Bacteria, and Turbidity from Raw Ohio River Water (99)

			% Removal				
Temperature C	State of flocculation	Coagulant	Coxsackie-virus A2*	Coliforms	Turbidity (ppm)** Initial	Turbidity (ppm)** Final	Final pH
	1	$Al_2(SO_4)3$	96	99	40-135	1-5	6.7-7.4
5	2	$FeCl_3$	94	62	1-5	0.1-1	7.3-7.7
	1 and 2		99.6	99.95	...	0.1-1	...
	1	$Al_2(SO_4)3$	95	94	140-255	1-5	6.7-7.4
15	2	$FeCl_3$	92	82	1-5	0.1	7.3-7.7
	1 and 2		99.6	99.9	...	0.1	...
	1	$Al_2(SO_4)3$	99	99.8	16-240	1-5	6.7-7.3
25	2	$FeCl_3$	94	94	1-5	0.1	7.3-7.8
	1 and 2		99.9	99.9	...	0.1	...

* Virus seeded into raw water before flocculation.
** Good flocs formed in all experiments.

cent bacteriophage T_4 and 90-94 per cent bacteriophage MS_2. In undiluted wastewater, percentage removal was greatly reduced due to the presence of interfering organic matter.

Ferric chloride may produce results similar to alum, only at higher doses. Manwaring et al (101) observed that a dose of 50-60 ppm ferric chloride brought about 99.3 percent removal of bacteriophage MS_2 in water. However, when 200 mg/l of sewage was added to the water, there was only a 67.2 percent reduction of the virus. These studies point to the fact that the coagulation-sedimentation process is most effective on effluents that have already been treated to remove organic matter.

Coagulation of activated sludge effluent with lime has resulted in greater than 95 percent removal of poliovirus 1 when the lime dosage was above 400 ppm (102). At lime concentrations over 400-500 ppm, the pH of the water is raised above 11.1, which is sufficient to destroy viruses quite rapidly.

As viruses are usually only physically removed by coagulation-sedimentation (except in the case of lime), they remain active in the sludge. Thus, proper care must be taken with sludge disposal.

e. Filtration

The main purpose of the filtration process is to remove suspended solids. Filtration is more efficient when used to remove viruses and bacteria from coagulated water and wastewater. Its efficiency will depend on many variables, especially filtration rate. Gilcreas and Kelley found that rapid sand filtration of coagulated spring water resulted in low removal of coxsackie virus A5, while slow sand filtration resulted in almost 98 percent removal of the virus (103). Berg found that slow sand filtration of a lime flocculated effluent resulted in 82-99 percent removal of poliovirus (102). As lime flocculation had resulted in 70-98.6 percent removal at doses from 200-500 mg/l, the total virus removal for coagulation-sedimentation-filtration was 98.6-99.9 percent.

Some plants filter coagulated raw water without sufficient time for flocs to settle. This may be efficient at first, but eventually floc breakthrough will occur along with virus breakthrough. It has been found that after adequate settling, even rapid sand filtration of flocculated effluent may be effective; however, often times coagulation-flocculation alone will bring about the same result (104). In this process, the virus is not destroyed, but only physically removed by adsorption of the virus-cation complex on sand.

2. Removal of Chemical Hazards

a. Removal of Trace Metals

Low levels of trace metals are often present in water due to industrial discharge. While such levels do not have an immediate public health impact on bathers, they may present long-term hygienic hazards when they are constantly present in man's water supply or become concentrated in man's food chain.

Neither primary nor secondary treatment are dependable processes for the removal of all trace metals. It has been found that lead and cadmium can be removed by typical primary treatment involving neutralization of equalized wastewater. In such a process, the metals would precipitate out in the hydroxide form (105). However, such a process is not effective for all metals. Barth et al (106) in a study of the effects of chromium (Cr +6) copper, zinc, and nickel on different treatment processes found removal to vary from 28% for nickel to 89% for zinc in primary sedimentation followed by activated sludge treatment.

More advanced treatment is needed to insure removal of all metals, and effective removal techniques have yet to be developed for all metals. Linstedt et al (107), studying the removal of cadmium, chromium, silver and selenium by an advanced treatment process consisting of coagulation and settling with lime, sand filtration, activated carbon and cation-anion exchange found concentrations of heavy metals to be greatly reduced by this process. Lime coagulation alone was quite successful (greater than 90% removal) in the removal of cadmium and silver. This degree of effectiveness was possibly caused because the metals were present as cations, and could easily be settled out in their hydroxide form.

Linstedt also found activated carbon to be quite effective in the removal of silver, cadmium and chromium, and ion-exchange to be effective in the removal of greater than 95% of all metals studied. In another study, Hinden found reverse osmosis to remove 70% cadmium, and 95% chromium from secondary effluents (108).

Trace metals may also have adverse effects on biological treatment processes. Barth (106) studied the effects of chromium (Cr +6), copper, nickel and zinc on the activated sludge treatment process. Lowered treatment efficiency was measured by an increase in BOD, COD, and turbidity. It was found that the following doses of these metals would significantly reduce the effectiveness of activated sludge treatment:

Metal	Concentration in Influent (mg/l)
Chromium (Cr +6)	10
Copper	1
Nickel	1 to 2.5
Zinc	5 to 10

It was also found that activated sludge treatment could take a much larger slug dose of these metals before effects would become harmful. Generally, the effects of slug doses depended on waste volume, the form of the metal, and the volume and character of the dilution water. Metals may also inhibit the nitrification process, causing large concentrations of ammonia in the treatment plant effluent. Large concentrations of ammonia greatly reduce the effectiveness of disinfection by chlorination.

Barth (106) also studied the effects of trace metals on the anaerobic digestion of primary and secondary sludges. The following concentrations of metals were found to be harmful to the digestion process:

Metal	Concentration in Influent (mg/l) Primary Sludge	Combined Sludge
Chromium (Cr +6)	750	750
Copper	10	5
Nickel	740	710
Zinc	10	10

Slug doses did not produce harmful effects, probably because the digestors were not in the main flow stream of treatment.

b. Removal of Nutrients

In many areas removal of the nutrients nitrogen and phosphorous from wastewater is essential, since these two elements have critical control over biological activity in ecosystems. Overabundance of these elements in the water environment may create excess plant growth which eventually results in the deterioration of water quality. Nitrogen in nitrate form is also a hazard in water used for drinking water, as concentrations above 10 mg/l as nitrogen may cause methemoglobinemia in infants (see page 41). Methods for phosphorous and nitrogen removal are discussed below.

1. Phosphorous Removal

The removal of phosphorous compounds may be achieved through chemical-biological treatment, chemical-physical treatment or ion-exchange (109).

Chemical-biological phosphate removal is accomplished by addition of a certain chemical to the aeration tank of an activated sludge unit or the filter influent of a trickling filter plant. Within the activated sludge unit, precipitation of phosphorous occurs in the aeration tank, and phosphorous is removed in the waste activated sludge. This process can produce an effluent with phosphorous concentrations of 1-2 mg/l (109). A variety of chemicals, including iron and aluminum salts and lime have been reported equally effective; and phosphorous removals of over 90% have been attained with the correct chemical to phosphorous ratio.

Another method for phosphorous removal is chemical-physical treatment in which phosphorous is removed through coagulation-precipitation followed by filtration. Pilot plant studies performed by Bell et al (110) found removals by this type of system to exceed 90%.

Yee (111) has demonstrated that ion-exchange, using activated alumina type A exchange resin, can achieve 99% removal of ortho-phosphate. Advantages of ion exchange over chemical precipitation are that ion-exchange is more highly selective for phosphorous; it involves no addition of extraneous ions; it has no effect on the pH of the water; it is not affected by variation in feed water quality, and it can achieve higher removals. However, fouling of ion-exchange beds with solids and organic matter, and the disposal of waste regenerant do pose difficult problems, making chemical precipitation the preferred method of phosphorous removal in locations where it is feasible.

2. Nitrogen Removal

Nitrogen removal may be achieved by the nitrification-denitrification process (109). Most of the nitrogen in wastewater is in the form of ammonia. Nitrification is the process by which ammonia is oxidized by the bacteria, *Nitrosomonas*, to nitrite. The nitrite is subsequently oxidized to nitrate by the bacteria, *Nitrobacter*. The nitrifying bacteria involved in this process use inorganic carbon present in activated sludge units as an energy source. Although nitrification does occur in the activated sludge units, the process requires longer aeration times and lower food to mass ratios than normally found in conventional activated sludge treatment.

Denitrification is a process by which nitrates are converted by bacteria to nitrogen gas. Denitrifying bacteria requires organic sources of carbon for energy and growth. Since most of the organic carbon present in wastewater has been oxidized by the activated sludge process, an external source of organic carbon is needed. Methanol is most commonly used as a carbon source, and it is usually added to carbon packed columns, where denitrification takes place. One mole of nitrogen requires approximately 5/6 mole of methanol for complete denitrification. With proper design, this process can achieve 90% nitrate removal. One problem involved in this process is slime formation in the carbon column. While slime will not interfere with the adsorbtion capacity of the carbon, its sloughing off can cause problems in further treatment processes.

Ammonia stripping is another effective method for nitrogen removal. In this process ammonia ions are converted to ammonia gas. This process begins by raising the pH of the wastewater to high levels by the addition of lime, as ammonia in water of high pH exists in a dissolved gaseous state, which can easily be liberated from wastewater. The water is then pumped to a cooling tower where it is broken into fine droplets that allow rapid transfer of ammonia gas from the water to the air. At warm temperatures, almost 95% nitrogen removal can be achieved (109). However, at temperatures below freezing ammonia removal drops considerably. Scale formation resulting from the addition of lime is also a problem, necessitating periodic shut down of the cooling tower for cleaning.

B. Land-Oriented Treatment

The Federal Water Pollution Control Act Amendments of 1972, with their goal of zero discharge, place a greater emphasis on land treatment of wastes than any previous water pollution legislation. Section 201 of the Act (Grants for Construction of Treatment Works) encourages recycling and reclamation of wastewater and the consideration of appropriate alternative waste management techniques providing for either recycling or reclaiming of wastewater or some other form of elimination of direct discharge of pollutants.

In Section 212 (2) (2) of the Act, the definition of treatment works includes land used as an integral part of the treatment process. Thus, the Amendments of 1972 not only aid the implementation of land treatment techniques, but encourages land treatment in areas where it is practicable.

Before the hygienic effects of effluent applied to the land can be evaluated, it is necessary to know the characteristics of the water being applied. The constituents of raw sewage and treatment plant effluents depend on the character of the municipal water supply, the industrial mix of the community, the proportion of commercial to residential development, and the nature of the residential community (112).

Pretreatment of raw waste is essential in land application to protect the public health, remove odors, and to improve the operational efficiency and reliability of the system (113). It is generally recommended that secondary or higher treatment be provided before land application, as this degree of treatment provides greater efficiency in the removal of hazardous substances. Table 12 lists drinking and irrigation water standards, as well as concentrations of substances in secondary treatment plant effluents. If proper techniques are followed, renovative mechanisms in the soil matrix will adequately decrease concentrations of hazardous substances. The major renovation mechanisms at work in the soil matrix include: uptake by plant roots, precipitation, adsorption, oxidation, ion exchange, and filtration (113). The effectiveness of these mechanisms in the removal of materials hazardous to the public health must be considered in the design of a land application system to insure the

TABLE 12

Selected Drinking-Irrigation Water Standards
vs. Typical Secondary Effluent Characteristics (27)

Substance	Drinking water (mg/liter)	Irrigation water (mg/liter)	Controlling concentration (mg/liter)	Secondary effluent (mg/liter)
BOD	1*	-	1	25
COD	1*	-	1	70
$^{+}NH_4$ (as N)	-	-	-	9.8
$^{-}NO_2$ (as N)	-	-	-	0.0
$^{-}NO_3$ (as N)	10	-	10	8.2
P	-	-	-	10
Phenols	0.001	-	0.001	0.3
Cadmium	0.01	0.005	0.005	0.1
Chromium	0.05	0.005	0.005	0.2
Copper	1.0	0.2	0.2	0.1
Iron	0.3	-	0.3	0.1
Lead	0.05	5.0	0.05	0.1
Manganese	0.05	2.0	0.05	0.2
Nickel	-	0.5	0.5	0.2
Zinc	5.0	5.0	5.0	0.2
Boron	-	0.75	0.75	0.7
Chlorides	250	-	250	100
Sulfates	250	-	250	125
Suspended solids	-**	-	5	25
Color	15	-	15	
Taste	Unobjectionable	-	Unobjectionable	
Odor	3	-	3	
Turbidity	5	-	5	
Aluminum	-	1.0	1.0	
Beryllium	-	0.5	0.5	
Selenium	0.01	0.05	0.01	
Silver	0.05	-	0.05	
Vanadium	-	10.0	10.0	
Arsenic	0.05	1.0	0.05	
Barium	1.0	-	1.0	
Cyanides	0.2	-	0.2	
Cobalt	-	0.2	0.2	

* Carbon chloroform extract to measure organic contaminants.
** Suspended solids should approach turbidity requirements.

protection of both water and food supplies.

1. <u>Removal of Biological Hazards</u>

Proper disinfection of effluents may remove almost 99% of pathogenic bacteria. However, viruses and parasitic ova are more resistant to the disinfection process.

Pathogens are futher removed from wastewater when applied to the land by a combination of straining, die off, sedimentation, entrapment, and especially adsorption (114). A considerable amount of field observations indicate that bacteria are removed from wastewater as they percolate through the soil. In fact, 92-97% of the pathogenic organisms present in wastewater effluent have been found to be removed in the upper 1 cm layer of the soil (116) if effluents are adequately chlorinated. Viruses may be transported to greater depths due to their smaller size, however, the distance is minimal. Drewry and Eliassen (117) determined that the passage of wastewater through 40-50 cm of agricultural-type soil is very effective in virus removal, provided there is an absence of direct chanelling through fissure, fractures, and dissolution channels or substrata with low adsorption capacity. They also found that virus retention in the soil is basically an adsorption process that is greatly affected by pH and cation content of the water-soil system. Viruses are amphoteric (functioning as a cation or anion) in behavior. As the pH of the water-soil system increases, there is an increased ionization of carboxyl groups on the virus protein sheath, which causes the virus to act as an anion (negatively charged particle). At the same time, the negative charge on soil particles increases with rising pH. However, the iso-electric point (point at which a substance is electrically neutral) of soil particles is less than that of viruses. At pH values between 7.0 and 7.5, viruses will behave as cations (positively charged particles), and are adsorbed by the anionic soil particles. Usually the pH of soils is higher than 7.5, but the cation content of the wastewater may lower the repulsive forces between soil and virus, allowing adsorption to take place. Besides pH, virus adsorption was also found to depend on ion-exchange capacity, clay content, organic carbon and glycerol retention capacity of the soil (117). Both viruses and bacteria are adsorbed but not destroyed, their survivial and potential threat in the soil is discussed in the "Residual Hazards" section.

2. <u>Removal of Chemical Hazards</u>

<u>Nitrogen Removal</u>

Biologically treated waste usually contains 5-30 mg/l total nitrogen (21). Nitrogen compounds are of great concern in the renovation of wastewater by land disposal, as concentrations of nitrate (NO_3) above 10 mg/l as nitrogen in drinking water present a potential threat of methemoglobinemia, a disease of infants which reduces the oxygen carrying capacity of blood.

Nitrogen in wastewater is found in four forms: organic, ammonium, nitrate and nitrite. The concentration of nitrate in wastewater is usually quite low as it is readily oxidized to nitrate in the presence of oxygen. Organic nitrogen, when applied to the land, is filtered out and decomposed to ammonium. Ammonium is preferentially adsorbed by agricultural soils and is bound tightly in this form. In this adsorbed phase, it is available to plant uptake, or under aerobic conditions, conversion to nitrate. Nitrates are not tightly bound to the soil and can be removed by plant uptake, or denitrification to nitrogen gas. Denitrification depends on both anaerobic conditions in the soil and its carbon content, as carbon is the source of energy for denitrifying bacteria. If nitrates are not denitrified, they may leach to groundwater or eventually reach surface waters where they may pose a threat to the public health. In general, nitrate removal varies from 0-95 percent depending on soil type, carbon to nitrogen ratio, depth of soil column, design and mode of application of the wastewater, and vegetative cover (115).

Removal of Heavy Metals

Heavy metals comprise another category of wastewater constituents that are of concern from a public health standpoint, as toxic effects may accompany their ingestion at low intake levels. Retention of heavy metals in the soil is brough about by adsorption, ion exchange, and to some extent, precipitation (113). Retention depends on the soil characteristics. Clean soils, such as sands and gravel, have little capacity to fix heavy metals and other inorganics primarily because they lack in-situ organics and clay minerals which bring about adsorption and ion-exchange (27). Anaerobic conditions in the soil tend to lower pH, as such conditions cause micro-organisms to generate volatile acids. At low pH, retained metals may be leached. However, addition of lime can raise pH and ensures fixation of metals (113). When both surficial and subsurface soil become saturated, heavy metals may not only leach out to contaminate water supplies but also destroy micro-organisms needed for removal of other contaminants (27). According to the Federal Water Pollution Control Act Amendments of 1972, toxic concentrations of heavy metals should not be present in secondary effluents, thus eliminating their threat in land application.

Removal of Total Dissolved Solids

Sodium and other dissolved minerals in water are significant when direct reuse is intended. It is estimated that a single use of water for domestic purposes will increase its mineral content by 100-300 mg/l. The most common soluble salts are sodium, potassium, magnesium, and calcium sulfates and chlorides. These salts are not retained significantly by the soil. Although some constituents are removed by ion-exchange, the total dissolved solids content of the wastewater does not change, as one mineral constituent is only replaced by another. Therefore, these constituents may limit the reuse cycle. High sodium content may be harmful to those suffering from cardiac, renal, and circulatory disease (27).

Removal of Organics

Suspended organics are almost completely removed from wastewater by filtration. Biodegradable suspended organics are oxidized by bacteria. This overall removal generally occurs in the top five to six inches of the soil (118) and a major portion is removed in just the top few centimeters. Dissolved organics are also usually removed by adsorption on clay and humic material. Degradable dissolved organics are easily oxidized under aerobic conditions by soil micro-organisms. However, the degradation process occurs quite slowly for resistant substances (113) such as chlorinated hydrocarbons and phenols. These substances usually remain in the soil as their leaching rate is slow. Chlorinated hydrocarbons are of increased concern if the site utilized includes application of pesticides. Some organics such as cellulose and humic substance are actually beneficial as they improve soil structure and adsorptive capacity (115).

3. Effects of Residuals in Soils

Residual Pathogens

After pathogens are removed by the soil matrix, their survival in the soil and on vegetation becomes a hygienic factor. Survival in the soil depends on the moisture content, temperature, textural and organic characteristics, aerobic and anaerobic condi-

TABLE 13

SURVIVAL TIMES OF ORGANISMS (120)

Organism	Media	Survival time
Anthrax bacteria	In water and sewage	19 days
Ascaris eggs	On vegetables	27-35 days
	On irrigated soil	2-3 years
	In soil	6 years
B. dysenteriae flexner	In water containing humus	160 days
B. typhosa	In water	7-30 days
	In soil	29-70 days
	On vegetables	31 days
Cholera vibrios	On spinach, lettuce	22-29 days
	On cucumbers	7 days
	On nonacid vegetables	2 days
	On onions, garlic, oranges, lemons, lentils, grapes, rice and dates	Hours to 3 days
Coliform	On grass	14 days
	On clover leaves	12-14 days
	On clover at 40-60% humidity	6 days
	On lucerne	34 days
	On vegetables (tomatoes)	35 days
	On surface of soil	38 days
	At -17 deg C	46-73 days
Entamoeba histolytica	On vegetables	3 days
	In water	Months
Enteroviruses	On roots of bean plants	At least 4 days
	In soil	12 days
	On tomato and pea roots	4-6 days
Hookworm larvae	In soil	6 weeks
Leptospira	In river water	8 days
	In sewage	30 days
	In drainage water	32 days
Liver fluke cysts	In dry hay	Few weeks
	In improperly dried hay	Over a year

TABLE 13 (Cont'd)

SURVIVAL TIMES OF ORGANISMS (120)

Organism	Media	Survival time
Poliovirus	In polluted water at 20 deg C	20 days
Salmonella	On grass (raw sewage)	6 weeks+
	On clover (settled sewage)	12 days
	On vegetables	7-40 days
	On beet leaves	3 weeks
	On grass	Over winter
	On surface of soil and potatoes	40 days+
	On carrots	10 days+
	On cabbage and gooseberries	5 days+
	In sandy soil - sterilized	24 weeks
	In sandy soil - unsterilized	5-12 weeks
	On surface of soil (raw sewage	46 days
	In lower layers of soil	70 days
	On surface of soils (stored sewage)	15-23 days
	In air dried, digested sludge	17 weeks+
Schistosoma ova	In digestion tanks	3 months
	In sludge at 60-75 deg F (dry)	3 weeks
	In septic tank	2-3 weeks
Shigella	On grass (raw sewage)	6 weeks
	On vegetables	7 days
Streptococci	In soil	35-63 days
	On surface of soil	38 days
S. typhi	In water containing humus	87-104 days
Tubercle bacteria	On grass	10-14 days
	In soil	6 months+
	In water	1-3 months
Typhoid bacilli	In loam and sand	7-17 days
	In muck	40 days
Vibrio comma	In river water	32 days
	In sewage	5 days

tions, and the activity of potentially rival microbial species. High moisture content, low temperature, and anaerobic conditions are conducive to longer survival. Competition for survival is greatest at the soil surface where there is more food due to decomposition of organic matter in the presence of oxygen. Rudolphs found Escherichia coli to survive longer in sterile soil than nonsterile soil due to lower competition. Rudolphs also found that Salmonella may survive in soil for 1/2 year to a year (119). Krone and McGaughy, however, found one month to be the maximum survival time of pathogenic organisms in the soil (118). Residual pathogens in the soil are a lesser threat to the public health as they have less probably contact with people here than in their transport to ground or surface water.

Although pathogenic organisms cannot penetrate healthy plants, their survival on edible plant surfaces must also be considered. However, if irrigation is stopped one month before harvesting, raw fruit and vegetables should not become vectors of disease due to natural die-off of pathogens. Sepp (120) lists survival times of various organisms in various types of media in table 13.

Residual Chemicals

Toxic metals may enter the food chain by application of effluents and sludge to the land, and their subsequent uptake by plants. Metals applied to land used for agriculture are not a hazard to the public health unless they enter the edible part of the plant. Elements in sludge and effluents that are potential hazards are boron, cadmium, cobalt, chromium, copper, mercury, nickel, lead and zinc (121). Chromium in its Cr^{+3} form does not accumulate in plants, nor does mercury accumulate appreciably in plants at levels normally found in sludges and effluents. Lead is not readily translocated to the edible parts of plants, and high phosphate levels in sludge and effluent can inhibit its uptake. Boron, copper, cobalt, nickel and zinc do accumulate in plants, but rarely reach levels injurious to man, as severe injury to the plant will occur before these levels are reached. Therefore, the only potential hazard to man is cadmium. Cadmium can concentrate in the edible portions of plants, and can accumulate in cattle fed on grains high in cadmium content. There is no FDA limit for cadmium in plants. The best recommendation is to keep the cadmium content at less than 0.5 percent, and preferably 0.1 percent, of the zinc content. By doing this, the zinc concentrations would ruin a crop before cadmium could become a health hazard (121). Although toxic metal concentrations seem to be a minor hazard to man when he is a primary feeder, it must be remembered that some of these substances may become concentrated along the food chain, presenting a threat to man as a secondary feeder.

4. Comparison of Land-Oriented Treatment

The three methods of land application are compared here on the basis of removal efficiency.

Spray Irrigation

Spray irrigation is the controlled spraying of liquid onto the land to support plant growth, at a rate measured in inches of liquid per week, with the flow path being infiltration and percolation within the boundaries of the disposal site (113). Rate of application of wastewater is usually two inches per week on soils, such as silt loam, with infiltration and percolation capacity sufficient to handle the design of loading of two inches of wastewater in an eight-hour period.

This method of land application is the most efficient in removing harmful substances (113). If groundwater is kept low, there will be no threat of pathogens as they are removed within the top few feet under optimum conditions. Loamy soils because of their large active surface area have considerable retention capacity for heavy metals by ion exchange and adsorption, especially when application rates are low.

A considerable amount of nitrogen removal results from plant uptake.

This method is also the best system for removal of organic compounds as aerobic conditions which are conducive to biodegradation exist in the soil most of the time due to alternating wet and dry periods. Also, the soil provides the right amount of penetration, and adequate contact and retention time for decomposition of organics (115).

In general, spray irrigation is most efficient because of soil texture, low application rates and removal of nutrients by crops (113).

Rapid Infiltration

Rapid infiltration is the controlled discharge, by spreading or other means of liquid onto the land at a rate measured in feet per week, with a flow path being high rate infiltration and percolation (113). Land application by this method is often referred to as groundwater recharge. Wastewater is usually applied to ponds for 10 to 14 days, during which anaerobic conditions exist. The pond is then allowed to dry for a period of time so that organic matter may be oxidized. Since higher percolation rates are required, coarser soil with lower clay content is needed. This type of soil has a greatly reduced active surface area and requires several hundred feet of contact to achieve the same renovation that five feet of spray irrigation column does.

Removal efficiency (percent removed/distance traveled) of pathogens by rapid infiltration is probably least efficient of land application methods; however, the distance traveled is longer, and the detention times is longer, so that percent removal is ultimately the same (115). Toxic metals must penetrate two to 30 times farther than in soils used for spray irrigation before they are removed due to the granular nature of the soil (113). This system is intermediate in removal of organics again due to coarser textured soils. Nitrate removal depends on the maintenance of the right balance of aerobic-anaerobic conditions in the soil. Aerobic conditions are necessary for conversion of ammonia to nitrate; and anaerobic conditions are necessary for denitrification, the prime mechanism for nitrate removal by rapid infiltration systems. Thus, nitrate removal will vary according to frequency of loading which determines the balance of aerobic-anaerobic conditions.

Overland Runoff

Overland runoff is the discharge by spraying or other means of liquid onto the land, at a rate measured in inches per week, with the flow path being downslope sheet flow (113). The clay soils used in this system are almost impervious. Thus, renovation is less efficient, as it is achieved mainly by movement of water over the soil surface, and plant growth, and the oxidation of solids. There is greater threat of contamination by pathogens; removal of organics and heavy metals is reduced; and total dissolved solids removal is least efficient (113). Nitrogen removal is comparable with other land application systems.

Estimated percentage removal of different substances by the three land application methods discussed is given in Table 14. (27).

These removals are not always possible, as optimum conditions may not always be maintained. Reported or estimated removal at currently existing operations is given in Table 15 (27).

TABLE 14 (27)

	% Removal SI	OR	RI
BOD	98+	98+	90-95
COD	95+	95+	90+
N	85+	85+	75-80
P	99+	85+	95+
Metals	95+	85+	95+
Suspended Solids	99	95+	99
Pathogens	99	99	99

SI - Spray Irrigation
OR - Overland Runoff
RI - Rapid Infiltration

TABLE 15 (27)

	% Removal		
	SI	OR	RI
BOD	98+	98	80-85
COD	95+	92	50-60
N	85+	80	75-80
P	99+	40-80	50-60
Metals	95+	50	50-60
Suspended Solids	99	94	99
Pathogens	99	99	99

SI - Spray Irrigation
OR - Overland Runoff
RI - Rapid Infiltration

III. EPA POLICY ON WATER REUSE

The U. S. Environmental Protection Agency, recognizing the ever-increasing demand for water through population growth and changing life styles has made the following policy statements on water reuse:

1. EPA supports and encourages the continued development and practice of successive wastewater reclamation, reuse, recycling and recharge as a major element in water resource management, providing the reclamation systems are designed and operated so as to avoid health hazards to the people or damage to the environment.

2. In particular, EPA recognizes and supports the potential for wastewater reuse in agriculture, industrial, municipal, recreational and groundwater recharge applications.

3. EPA does not currently support the direct interconnection of wastewater reclamation plants with municipal water treatment plants. The potable use of renovated wastewaters blended with other acceptable supplies in reservoirs may be employed once research and demonstration has shown that it can be done without hazard to health. EPA believes that other factors must also receive consideration, such as the ecological impact of various alternatives, quality of available sources and economics.

4. EPA will continue to support reuse research and demonstration projects including procedures for the rapid identification and removal of viruses and organics, epidemiological and toxicological analyses of effects, advanced waste and drinking water treatment process design and operation, development of water quality requirements for various reuse opportunities, and cost-effectiveness studies.

IV. PUBLIC HEALTH CONSIDERATIONS IN SLUDGE UTILIZATION AND DISPOSAL

Sludge is a liquid containing contaminants removed from wastewater by physical, chemical, and biological treatments. Since a typical waste activated sludge from biological treatment contains well over 100 tons of water for each ton of solids, sludge disposal is mainly a problem of disposing of the water that is in close association with waste solids (122). Estimates of sludge produced in the United States per day range from 10,000 tons/day to 20,000 tons/day. These estimates do not include industrial users of municipal treatment plants (123).

Domestic sewage sludge is primarily organic in nature, although significant quantities of toxic chemicals such as heavy metals and chlorinated hydrocarbons may be present due to plumbing systems and streat and agricultural runoff. In areas where industrial wastewaters are treated, concentrations of toxic substances in treatment plant sludges are increased. Furthermore, many of the pathogenic organisms found in sewage may survive wastewater treatment processes, and are quite commonly found in sludge. Because sludge potentially contains so many hazardous substances, its disposal may have adverse effects on various phases of the environment.

Recent concern over the environmental impact of residues or sludges from wastewater treatment plant processes has led to many reports, legislation, and regulations regarding its ultimate disposal (123).

In 1970 the Council on Environmental Quality, in its report, "Ocean Dumping - A National Policy", recommended that ocean dumping of undigested sewage sludge be stopped as soon as possible and no new sources allowed, and that ocean dumping of digested or stabilized sludge be phased out and no new sources allowed. In accordance with these recommendations, the Environmental Protection Agency issued an interim policy in 1971 prohibiting the issuance of grants for treatment works which would dispose of sludge to the ocean.

The Federal Water Pollution Control Act Amendments of 1972 contain many provisions that are directly related to the ultimate disposal of treatment plant residues. These provisions are listed below:

1. Under Title II of the Act the Administrator of the Environmental Protection Agency makes grants for the construction of treatment works.

2. Under Section 203(a) of the Act, each applicant for a grant submits to the Administrator for his approval, plans, specifications and estimates for each proposed project for the construction of treatment works for which a grant is applied.

3. Under Section 201(d)(4), the Administrator shall encourage waste treatment management which results in the construction of revenue producing facilities providing for the ultimate disposal of sludge in a manner that will not result in environmental hazards.

4. In Section 212(2)(A), the term, treatment works, is

defined to include site acquisition of the land that will be an integral part of the treatment process or is used for ultimate ids-posal of residues resulting from such works.

5. Section 405 of the Act requires that there be no ocean discharge of sludge without a permit, and permits are to be issued only when it is in the public interest.

6. Finally, Section 301 requires that all publicly owned treatment plants process their waters so that effluent limitations based on secondary treatment are achieved by 1977. Secondary treatment will result in large increases of sewage sludge, since, under the definition of secondary treatment, 85 percent of suspended solids will have to be removed from municipal wastewater effluents.

Due to the influence of the CEQ report, and the sections of the Act requiring permits for ocean disposal of treatment plant sludge and a minimum of secondary treatment for all publicly-owned treatment plants by 1977, the quantity of sewage sludge to be disposed of is constantly increasing. Sections 201 and 212 of the Act encourage land disposal. However, the legislation does not specify exactly what methods of sludge utilization or disposal are environmentally acceptable. The Environmental Protection Agency established a work group in 1972 to develop a positive Agency policy concerning acceptable methods, based upon current knowledge, for the utilization or disposal of sludges from publicly owned wastewater treatment plants. This work group has published a sludge policy statement which defines acceptable methods for the utilization or disposal of sludge. It is divided into two essential parts; the first part describes sludge utilization methods, in which sludge is used to serve a useful purpose beyond mere disposal, and the second part describes methods which provide only for disposal. Both parts include only methods which are considered acceptable from an environmental and, in particular, a public health standpoint.

These methods are discussed below along with their public health implications.

A. <u>Sludge Utilization Methods</u>

These methods include stabilization and subsequent land application of sludges for agriculture, enhancement of parks, forests, and reclamation of poor or damaged terrain (123).

Stabilization of sludge reduces public health hazards and nuisance conditions such as odors and insects. To be acceptable, the stabilization method used must reduce influent volatiles by 40 percent, and fecal coliform counts by at least 97%. Methods of sludge stabilization are:

1. <u>Anaerobic Digestion</u>

Anaerobic (or oxygen-free) digestion is the controlled putrefaction of raw sludge. If sewage is held in a well designed and operated digester for 30 days at a temperature of at least 30°C, up to half the organic matter of volatile solids will be converted to gases by methane fermentation, and the fecal coliform count will be reduced by over 97% due to natural die-off with time (123). However, it has been found that anaerobic digestion will not destroy all pathogens such as parasites and viruses. Chang (124) found that although a 30 day detention period destroyed helminth ova, ascaris ova were not affected by a 3 month detention time. He also found the coxsackie B_5 virus to survive 30 days of anaerobic digestion. This stabilization process is also sensitive to toxic substances, such as heavy metals.

2. Composting

Sludge can be further stabilized by various composting systems. If composting is used, temperatures above 55°C must be reached as a result of oxidative bacterial action. After composting the material must be cured in a stockpile for at least 30 days to control odors (123).

3. Aerobic Digestion

Aerobic stabilization involves aeration of waste sludges until a large part of volatile solids have been destroyed. This process is more stable than anaerobic digestion as it is not sensitive to toxic influents; however, it does not generate its own fuel gas for aeration (122).

4. Lime Treatment

As an alternative to digestion, sludge may be stabilized by lime to a pH near 12. Lime treatment provides a high level of disinfection, but it does not destroy organic matter. However, if limed sludge is spread on a well aerated soil, aerobic organisms will consume organic matter, and no odors should be produced. In addition, most soils and crops are benefited by the addition of lime (122).

5. Pastuerization

Pastuerization (thermal treatment at high temperatures) is used quite commonly in Europe for digested sludge that is spread on pastures during grazing seasons. Twenty-five to thirty minutes heating at 70°C is recommended to kill almost all pathogens. Heat treatment above 160°C for one half hour will destroy all living organisms. If oxygen is present, a considerable amount of organic matter will also be oxidized (122).

After stabilization, liquid digested sludge may be applied to the land by plow injection, ridge and furrow spreading, or spray application. Dried sludge or composted material from digested sludge may either be spread on the land or incorporated in the soil. Public health precautions in land application of sludges include (123):

(1) Workers must be protected during transportation and application of sludge.

(2) Public access to both open storage lagoons and the application site itself must be prevented.

(3) When spray application is used, transport of

aerosols must be minimized with low pressure, large droplet spray devices, and placement of spray nozzles close to the ground, directed in a downward direction. Wide buffer zones around the application site will also minimize the hazards of aerosols.

(4) When sludge is used on crops, measures must be taken to prevent harmful contaminants from entering the food chain. All sludge application projects involving crops in the human food chain must be reviewed by the U. S. Department of Agriculture, and the Food and Drug Administration. The USDA has set the following maximum levels for metals in sludges applied to crops in the human food chain:

Element	Level (mg/kg)
Cd	10
Cu	1,000
Hg	10
Ni	200
Pb	1,000
Zn	2,000

(Further discussion of the hazards of metals in land application to food crops is found on page 87)

It is generally required that industrial users of wastewater treatment plants pretreat their wastes to minimize heavy metals and other toxic chemicals.

The Food and Drug Administration is presently developing limits for trace elements in foods. Also, since conventional wastewater treatment does not produce a pathogen-free sludge, FDA does not approve of the application of sludge to crops which may be eaten raw by humans. Pathogens may survive on the surfaces of plants and fruits for time periods of a few hours to several months (see Table 14). Generally, longer survival times depend on low temperatures, high soil moisture, neutral soil, presence of large amounts of organic matter, and in lack of competitor microorganisms.

(5) Ponding on application sites must be eliminated to prevent mosquito breeding. Ponding may be prevented by proper grading, effective maintenance, and light application rates.

(6) Groundwater which is in the zone of saturation must be protected so that water quality parameters will not exceed standards set by EPA. Soil depth to fissured rock, highly permeable gravel, or groundwater itself must be sufficient to prevent contamination. The pH of the combined sludge and soil mixture should be above 6.5 to prevent solubilization of metal ions. The nitrogen content of the sludge may limit application rates, as high nitrates are harmful in drinking water. Groundwater near sludge application sites must be carefully monitored for pathogens and other toxic substances.

(7) Surface water runoff must also be controlled to prevent migration of sludge material to surface water supplies. This may be done by containment, controlled release of runoff, and erosion control methods. A typical land application site should be flat to minimize runoff, and the soil should be permeable. Vegetative covers are recommended to stabilize the soil and to control erosion and runoff. Surface water near application sites must also

be monitored for pathogens and toxic materials.

B. Sludge Disposal Methods

Disposal methods include sludge landfills involving mixed sludge and solid wastes or sludge incineration with disposal of resultant ash. Ocean disposal is considered acceptable by EPA for treatment works currently using this method when sludge meets the criteria specified by EPA in its ocean dumping regulations.

1. Sludge Landfills

Sanitary landfills of sludge containing no free moisture either separately or mixed with solid wastes must be designed and operated according to EPA Guidelines for Land Disposal of Solid Wastes (123). To protect the public health:

(1) Sludge must be stabilized.

(2) A daily soil cover must be applied to the landfill.

(3) Workers must be supplied with individual protection.

(4) Both groundwater and surface water must be protected and monitored as in land application of sludges.

2. Sludge Incineration and Disposal of Ash

Incineration alone is a sludge volume reduction method, not a method for ultimate disposal. Ash, either in its dry form, or in scrubber water, may be disposed of in a sanitary landfill.

To protect the public health, the following conditions should be met (123):

(1) The incinerator must be designed to operate at a temperature of 1600°F; and the minimum residence time at this temperature must be 2 seconds. Such conditions destroy most organic chemicals.

(2) Emissions from the incinerator must meet the air pollution emissions standards of performance-"New Source Performance Standards for Sludge Incinerators". Fly ash may be removed from incinerators by wet scrubbers, cyclones, electrostatic precipitators, or bag filters. However, wet scrubbers are the best removal devices as they remove, in addition to ash, nitrogen and sulfur compounds, and hydrochloric acid. Stack emissions must be constantly monitored.

(3) Industry must pretreat its wastewaters to remove such toxic elements as mercury and persistant organics which vaporize on incineration.

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V. Massachusetts Water Quality Standards

The Commonwealth of Massachusetts

OFFICE OF THE SECRETARY
STATE HOUSE, BOSTON, MASS.

Rules and Regulations filed in this Office under the provisions of CHAPTER 30A as amended.

Filed by WATER RESOURCES COMMISSION DIVISION OF WATER POLLUTION CONTROL

Rules and Regulations for the Establishment of Minimum Water Quality Standards & For the Protection of the Quality & Value of Water Resources

Date Filed May 2, 1974

Date Published May 13, 1974

Chapter 233, sec. 75

Printed copies of rules and regulations purporting to be issued by authority of any department, commission, board or Officer of the Commonwealth or any city or town having authority to adopt them, or printed copies of any ordinances or town by-laws, shall be admitted without certification or attestations, but if this genuineness is questioned, the court may require such certifications or attestations thereof as it deems necessary.

Attested as a true copy
JOHN F. X. DAVOREN
John F. X. Davoren
SECRETARY OF THE COMMONWEALTH

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RULES AND REGULATIONS
FOR THE ESTABLISHMENT OF
MINIMUM WATER QUALITY STANDARDS
AND FOR THE PROTECTION OF THE
QUALITY AND VALUE OF WATER RESOURCES

REGULATION I Definitions

The terms used in the following regulations are defined as follows:

1. Appropriate Treatment - means that degree of treatment required for the waters of the Commonwealth to meet their assigned classifications or any terms, conditions, or effluent limitations established as part of any permit to discharge issued under the provisions of the Massachusetts Clean Waters Act, or any effluent standard or prohibition established by the Division under authority of Section 27 (6) of the Massachusetts Clean Waters Act.

2. Division - means the Commonwealth of Massachusetts, Division of Water Pollution Control.

3. Person - means any agency or political subdivision of the Commonwealth, public or private corporation or authority, individual, partnership or association, or other entity, including any officer of a public or private agency or organization, upon whom a duty may be imposed by or pursuant to any provision or Sections 26-53 inclusive, of Chapter 21 of the General Laws.

4. Sewage - means the water-carried waste products or discharges from human beings sink wastes, wash water, laundry waste and similar so-called domestic waste.

5. The "Waters of the Commonwealth" and "Waters" - means all waters within the jurisdiction of the Commonwealth, including, without limitation, rivers , streams, lakes, ponds, springs, impoundments, estuaries, coastal waters, and ground waters.

6. Fresh Waters - means waters not subject to the rise and fall of the tide.

7. Salt Waters - means all waters subject to the rise and fall of the tide.

8. Cold Water Stream - means a stream capable of sustaining a population of cold water fish, primarily Salmonids.

9. Seasonal Cold Water Stream - means a stream which is only capable of sustaining cold water fish during the period of September 15 through June 30.

10. Waste Treatment Facility - processes, plants, or works, installed for the purpose of treating, neutralizing, stabilizing or disposing of wastewater.

11. Pollutant - means any element or property of sewage, agricultural, industrial, or commercial waste, run-off, leachate, heated effluent, or other matter in whatever form and whether originating at a point or non-point source, which is or may be discharged drained or otherwise introduced into the waters of the Commonwealth.

12. Discharge - means the flow or release of any pollutant into the waters of the

Commonwealth.

13. Wastewater - means sewage, liquid or water carried waste from industrial, commercial, municipal, private or other sources.

14. Zone of Passage - means a continuous water route of the volume, area and quality necessary to allow passage of free-swimming and drifting organisms with no significant effect produced on the population.

Regulation II - Water Quality Standards

1 - The Water Quality Standards adopted by the Massachusetts Division of Water Pollution Control on March 3, 1967 and filed with the Secretary of State on March 6, 1967 are hereby repealed, except that existing "River Basin Classifications" based on the 1967 Standards will remain in full force and effect until reclassified in accordance with the following standards.

2 - To achieve the objectives of the Massachusetts Clean Waters Act and the Federal Water Pollution Control Act Amendments of 1972 and to assure the best use of the waters of the Commonwealth the following standards are adopted and shall be applicable to all waters of the Commonwealth or to different segments of the same waters:

3 - Fresh Water Standards

Class A - These waters are designated for use as sources of public water supply in accordance with the provisions of Chapter 111 of the General Laws.

Water Quality Criteria

Item	Criteria
1. Dissolved oxygen	Not less than 75% of saturation during at least 16 hours of any 24 hour period and not less than 5 mg/l at any time. For cold water streams the dissolved oxygen concentration shall not be less than 6 mg/l. For seasonal cold water streams the dissolved oxygen concentration shall not be less than 6 mg/l during the season.
2. Sludge deposits-solid refuse-floating solids-oil-grease-scum	None allowable
3. Color and turbidity	None other than of natural origin.

4. Total Coliform bacteria per 100 ml.	Not to exceed an average value of 50 during any monthly sampling period.
5. Taste and odor	None other than of natural origin
6. pH	As naturally occurs
7. Allowable temperature increase	None other than of natural origin.
8. Chemical constituents	None in concentrations or combinations which would be harmful or offensive to humans, or harmful to animal or aquatic life.
9. Radioactivity	None other than that occurring from natural phenomena.

Class B - These waters are suitable for bathing and recreational purposes, water contact activities, acceptable for public water supply with treatment and disinfection, are an excellent fish and wildlife habitat, have excellent aesthetic values and are suitable for certain agricultural and industrial uses.

Item	Criteria
1. Dissolved oxygen	Not less than 75% of saturation during at least 16 hours of any 24 hour period and not less than 5 mg/l at any time. For cold water streams the dissolved oxygen concentration shall not be less than 6 mg/l. For seasonal cold water streams the dissolved oxygen concentration shall not be less than 6 mg/l during the season.
2. Sludge deposits-solid refuse-floating solids-oil-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.

3. Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4. Coliform bacteria per 100 ml	Not to exceed an average value of 1000 nor more than 1000 in 20% of the samples.
5. Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish.
6. pH	6.5 - 8.0
7. Allowable temperature increase	None except where the increase will not exceed the recommended limit on the most sensitive receiving water use and in no case exceed 83°F in warm water fisheries, and 68°F in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.
8. Chemical constituents	None in concentrations or combinations which would be harmful or offensive to human, or harmful to animal or aquatic life or any water use specifically assigned to this class.
9. Radioactivity	None in concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Class B1 - The use and criteria for Class B1 shall be the same as for Class B with the exception of the dissolved oxygen requirement which shall be as follows for this class:

Item	Criteria
1. Dissolved oxygen	Not less than 5 mg/l during at least 16 hours of any 24 hour period, nor less than 3 mg/l at any time. For seasonal cold water fisheries at least 6 mg/l must be maintained during the season.

Salt Water Standards

Class SA - These are waters of the highest quality and are suitable for any high water quality use including bathing and other water contact activities. These waters are suitable for approved shellfish areas and the taking of shellfish without depuration, have the highest aesthetic value and are an excellent fish and wildlife habitat.

WATER QUALITY CRITERIA

Item	Criteria
1. Dissolved oxygen	Not less than 6.5 mg/l at any time.
2. Sludge deposits-solid refuse-floating solids-oil-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3. Color and turbidity	None in such concentrations that will impair any uses specifically assigned to this class.
4. Total Coliform bacteria per 100 ml	Not to exceed a median value of 70 and not more than 10% of the samples shall ordinarily exceed 230 during any monthly sampling period.
5. Taste and odor	None allowable
6. pH	6.8 - 8.5
7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the waters for any other uses.

9. Radioactivity	None in concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Class SB - These waters are suitable for bathing and recreational purposes including water contact sports and industrial cooling, have good aesthetic value, are an excellent fish habitat and are suitable for certain shell fisheries with depuration (Restricted Shellfish Areas).

Water Quality Criteria

Item	Criteria
1. Dissolved oxygen	Not less than 5.0 mg/l at any time.
2. Sludge deposits-solid refuse-floating solids-oils-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing adequate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3. Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4. Total Coliform bacteria per 100 ml	Not to exceed an average value of 700 and not more than 1000 in more than 20% of the samples.
5. Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
6. pH	6.8 - 8.5

Salt Water Standards

Class SA - These are waters of the highest quality and are suitable for any high water quality use including bathing and other water contact activities. These waters are suitable for approved shellfish areas and the taking of shellfish without depuration, have the highest aesthetic value and are an excellent fish and wildlife habitat.

WATER QUALITY CRITERIA

Item	Criteria
1. Dissolved oxygen	Not less than 6.5 mg/l at any time.
2. Sludge deposits-solid refuse-floating solids-oil-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3. Color and turbidity	None in such concentrations that will impair any uses specifically assigned to this class.
4. Total Coliform bacteria per 100 ml	Not to exceed a median value of 70 and not more than 10% of the samples shall ordinarily exceed 230 during any monthly sampling period.
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6. pH	6.8 - 8.5
7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the waters for any other uses.

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Water Quality Criteria

Item	Criteria
1. Dissolved oxygen	Not less than 5.0 mg/l at any time.
2. Sludge deposits-solid refuse-floating solids-oils-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing adequate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3. Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4. Total Coliform bacteria per 100 ml	Not to exceed an average value of 700 and not more than 1000 in more than 20% of the samples.
5. Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
6. pH	6.8 - 8.5

7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the water for any other use.
9. Radioactivity	None in such concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Class SC - These waters are suitable for aesthetic enjoyments, for recreational boating, as a habitat for wildlife and common food and game fishes indigenous to the region, and are suitable for certain industrial uses.

WATER QUALITY CRITERIA

Item	Criteria
1. Dissolved oxygen	Not less than 5 mg/l during at least 16 hours of any 24 hour period nor less than 3 mg/l at any time.
2. Sludge deposits-solid refuse-floating solids-oil-grease-scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3. Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4. Total Coliform bacteria	None in such concentrations that would impair any uses specifically assigned to this class. see Note 2

5. Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
6. pH	6.5 - 8.5
7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the water for any other use.
9. Radioactivity	None is such concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Note 2 - no bacteria limit has been placed on Class "SC" waters because of the urban runoff and combined sewer problems which have not yet been solved. In waters of this class not subject to urban runoff or combined sewer discharges the bacterial quality of the water should be less than an average of 5,000 coliform bacteria/100 ml during any monthly sampling period. It is the objective of the Division to eliminate all point and non-point sources of pollution and to impose bacterial limits on all waters.

REGULATION III - General Provisions

1. It is recognized that certain waters of the Commonwealth possess an existing quality which is better than the standards assigned thereto.

A. Except as otherwise provided herein, no new discharge of wastewater will be permitted into any stream, river or tributary upstream of the most upstream discharge of wastewater from a municipal waste treatment facility or municipal sewer discharging wastes requiring appropriate treatment as determined by the Division. Any person having an existing wastewater discharge shall be required to cease said discharge and connect to a municipal sewer unless it is shown by said person that such connection is not available or feasible. Existing discharges not connected to a municipal sewer will be provided with the highest and best practical means of waste treatment to maintain high water quality. New discharges from a municipal waste treatment facility into such waters will be permitted provided that such discharge is in accordance with a plan developed under the provisions of Section 27(10) of Chapter 21 of the General Laws (Massachusetts Clean Waters Act) which has been the subject of a Public Hearing and approved by the Division. The discharge of industrial liquid coolent wastes in conjunction with the public and private supply of heat or electrical power may be allowed provided that a permit has been issued by the Division and that such discharge is in conformance with the terms and conditions of the permit and in conformance with the water quality standards of the receiving waters.

B. Except as otherwise provided herein no new discharge of wastewater will be permitted in Class SA or SB waters. Any person having an existing discharge of wastewater into Class SA or SB waters will be required to cease said discharge and to connect to a municipal sewer unless it is shown by said person that such connection is not available or feasible. Existing discharges not connected to a municipal sewer will be provided with the highest and best practical means of waste treatment to maintain high water quality. New discharges from a waste treatment facility into such waters will be permitted provided that such discharge is in accordance with a plan developed under the provisions of Section 27(10) of Chapter 21 of the General Laws (Massachusetts Clean Waters Act) which has been the subject of a Public Hearing and approved by the Division. The discharge of industrial liquid coolent wastes in conjunction with the public and private supply of heat or electrical power may be allowed provided that a permit has been issued by the Division and that such discharge is in conformance with the terms and conditions of the permit and in conformance with the Water Quality Standards of the receiving waters.

2. The latest edition of the Federal publication "Water Quality Criteria" will be considered in the interpretation and application of bioassay results.
3. The latest edition of Standard Methods For Examination of Water and Wastewater, American Public Health Association, will be followed in the collection, preservation, and analysis of samples. Where a method is not given in the standards methods, the latest procedures of the American Society for Testing Materials (ASTM) will be followed.
4. The average minimum consecutive 7-day flow to be expected once in 10 years shall be used in the interpretation of the standards.
5. In the discharge of waste treatment plant effluents into receiving waters, consideration shall be given both in time and distance to allow for mixing of effluent and stream. Such distances required for complete mixing shall not effect the water use classifications adopted by the Division. However, a zone of passage must be provided wherever mixing zones are allowed.

6. There shall be no new discharges of nutrients into lakes or ponds. In addition, there shall be no new discharge of nutrients to tributaries of lakes or ponds that would encourage eutrophication or growth of weeds or algae in these lakes or ponds.

7. Any existing discharge containing nutrients in concentrations which encourage eutrophication or growth of weeds or algae shall be treated to remove such nutrients to the maximum extent technically feasible.

8. These Water Quality Standards do not apply to conditions brought about by natural causes.

9. All waters shall be substantially free of products that will (1) unduly affect the composition of bottom fauna, (2) unduly affect the physical or chemical measure of the bottom, (3) interfere with the spawning of fish or their eggs.

10. No person shall discharge any pollutants into any waters of the Commonwealth which shall cause a violation of the standards.

11. A person shall submit to the Division for approval all plans for the construction of or addition to any waste treatment facility and no such facility may be constructed, modified or enlarged without such approval.

12. Cold water and seasonal cold water streams shall be those listed by the Massachusetts Division of Fisheries and Game.

13. Whoever violates any provision of these regulations shall (a) be fined not less than two thousand five hundred dollars nor more than twenty-five thousand dollars for each day of such violation or its continuance, or by imprisonment for not more than one year, or by both; or (b) shall be subject to a civil penalty not to exceed ten thousand dollars per day of such

violation, which may be assessed in an action brought on behalf of the Commonwealth in any court of competent jurisdiction, pursuant to Section 42 of Chapter 21 of the Massachusetts General Laws.

14. The Division and its duly authorized employees shall have the right to enter at all reasonable times into or on, any property, public or private, for the purpose of inspecting and investigating conditions relating to pollution or possible pollution of any waters of the Commonwealth, pursuant to Section 40 of Chapter 21 of the Massachusetts General Laws.

15. If any regulation, paragraph, sentence, clause, phrase or word of these regulations shall be declared invalid for any reason whatsoever, that decision shall not effect any other portion of these regulations, which shall remain in full force and effect and to this end the provisions of these regulations are hereby declared severable.

Approved by Commissioner of
Public Health

Date: Apr 9, 1974

William J. Bicknell, M.D.

Adopted by Division of
Water Pollution Control

Date: April 11, 1974

Thomas C. McMahon, Director

A true copy,
attest:

NOTARY PUBLIC,
MY COMMISSION EXPIRES SEPTEMBER 1, 1978

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VI. Stream Classifications and Existing Water Quality Within the Merrimack River Basin

TABLE A

NASHUA RIVER BASIN	CLASSIFICATION	EXISTING CONDITIONS*
Squannacook River	B	B
Squannacook Tributary	B	B
Nissitissit River	B	D
Phillips Brook	B	D
Whitman River	B	C
Round Meadow Pond Tributary	B	D
Round Meadow Pond Brook	B	D
Flag Brook	B	B
North Nashua River	C	C
Fall Brook	B	C
Wekepeke Brook	B	B
Stillwater River	A	
Gamma Brook	A	A
Ball Brook (Sterling)	A	B
Scanlon Brook	A	B
Waushacum Brook	A	B
South Wachusett Brook	A	
Quinapoxet River	A	
Muschopauge Brook	A	A
Maynard Brook	A	B
Bumbo Brook	A	A
Alpha Brook	A	A
Governor Brook	A	B
Ball Brook (Holden)	A	B
Asnebumskit Brook	A	D
Wachusett's Reservoir	A	
Gates Brook	A	B
Scarlett's Brook	A	B
Poor Farm Brook	A	B
Chaffin Pond Tributary	A	B
French Brook	A	C
Nashua River	C	D
Catacoonamug Brook	B	C
Nonacoicus Brook	B	C
Flanagan Pond Brook	B	B
James Brook	B	C
Wrangling Brook	B	B
Reedy Meadow Brook	B	D

* Based on Water Quality Data Collected Aug - Dec 1973, March - May 1974, list in this report.

TABLE A (Cont.)

MERRIMACK RIVER BASIN	CLASSIFICATION	EXISTING CONDITIONS
Merrimack River	B, C, SA, SB, & SC	C & D
Mascuppic Lake Outlet	B	D
Deep Brook	B	
Black Brook	B	D
Fish Brook	B	C
Lake Cochichewick Outlet	B	B
Johnson Creek	B	B
East Meadow River	B	B
Cobbler Brook	B	D
Bare Meadow Brook	B	C
Stony Brook	B	D
Boutwell Brook	B	D
Beaver Brook	B	D
Long Pond Outlet	B	C
Spicket River	B	D
Harris Brook	B	A
Powwow River	B	D
Black Rock Creek	SB	SB
SUASCO REGION		
Assabet River	B & C	D
Hop Brook	B	C
Rawson Hill Brook	B	C
Sunken Meadow Brook	B	D
Crystal Spring	B	C
Second Division Brook	B	C
Fort Pond Brook	B	B
Hager Pond Brook	B	D
Tributary @ Hudson Line	B	D
Elizabeth Brook	B	B
Sudbury River	B	B
Sudbury Reservoir	A	
Taylor Brook	A	C
Lake Cochituate	B	
Concord River	B & C	B & C
Farley Brook	B	B
Putnam Brook	B	C
Beaver Brook	B	B
Pond Brook	B	B
River Meadow Brook	B	C
Nashoba Brook	B	B

TABLE A (Cont.)

SUASCO REGION (Cont.)	CLASSIFICATION	EXISTING CONDITIONS
Nonset Brook	B	B
Nagog Brook	B	B
SHAWSHEEN RIVER BASIN		
Shawsheen River	B	C
Webb Brook	B	C
Strong Water Brook	B	D
*Tributary in Tewksbury	B	D

* Reference can be made to map showing sampling point locations as they represent points 72 and 72a respectively.

VII. EPA PROPOSED RAW WATER QUALITY CRITERIA FOR PUBLIC WATER SUPPLY*

Table C

PARAMETER	PROPOSED CRITERIA
Alkalinity	No Limit
Ammonia (as N)	0.5 mg/l
Arsenic	0.1 mg/l
Bacteria	10,000/100 ml Total Coliform 2,000/100 ml Fecal Coliform
Barium	1.0 mg/l
Boron	1.0 mg/l
Cadmium	0.01 mg/l
Chloride	250.0 mg/l
Chromium (as Cr^{+6})	0.05 mg/l
Color	75 units (Co-Pt)
Copper	1.0 mg/l
Cyanide	0.2 mg/l
Dissolved Oxygen	Near Saturation
Iron	0.3 mg/l
Lead	0.05 mg/l
Manganese	0.05 mg/l
Mercury	0.002 mg/l
Nitrate-Nitrite (as N)	Nitrate=10.0 mg/l Nitrite=1.0 mg/l
Nitrilotriacetate (NTA)	No Limit-insufficient information

PARAMETER	PROPOSED CRITERIA
Odor & Taste	Not Detectable
Oil & Grease	Not Detectable
pH	Range from 5 - 9
Phenolic Compounds	0.001 mg/l
Phosphate (as P)	No Limit Set
Selenium	0.01 mg/l
Silver	0.05 mg/l
Sodium	See A below
Sulfate (as SO_4)	250.0 mg/l
Temperature	Should not detract from potability or interfere with treatment process
Turbidity	No Limit Set
Virus	No Limit-Insufficient information
Zinc	5.0 mg/l

A. Assuming a per capita consumption rate of 2 liters of water per day, the American Heart Association recommends a maximum concentration of 20 mg/l. For those people not on a sodium restricted diet, a miximum concentration of 270 mg/l is recommended. The question remains as to what population needs you meet.

* Proposed Criteria for Water Quality, Volume I, II, and III, U.S. Environmental Protection Agency, October, 1973.

VIII. U.S.DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

Soil Limitations for Septic Tank Sewage Disposal

The expansion of residential areas into rural or rural-fringe areas is resulting in the construction of homes in many areas that are not serviced by a communal sewer system. In such areas, sewage disposal is dependent on individual systems utilizing septic tanks and disposal fields. The successful functioning of this kind of disposal system depends largely on the absorptive ability of the soil and the level of the water table during wet seasons. Some soils can absorb sewage effluent. Other soils cannot absorb sewage effluent regardless of the size of the disposal field. In rating soils for septic tank sewage disposal, it is assumed that house lots will be about 1/2 acre in size.

The major factors by which the soils are rated for the disposal of effluent from septic tanks are:

a. soil permeability,

b. depth to seasonal high water table,

c. depth to bedrock, hardpan, or clay or silt layers,

d. slope of the land,

e. flooding by stream overflow,

f. surface rockiness,

g. surface stoniness.

Three degrees of limitation for septic tank sewage effluent disposal are shown on the map, "Soil Limitations for Septic Tank Sewage Disposal." The use of this map does not eliminate the need for on-site investigations to determine conditions at a specific site.

The three degrees of limitation are defined as follows:

1 - <u>Slight limitation</u>

No special problems are expected to be encountered when these soil areas are used for septic tank systems. Septic tank disposal systems designed and installed in accordance with normal approved specifications should operate satisfactorily.

The soils are well drained through excessively drained. They have formed in sandy and gravelly materials and have few or no stones on the surface or below. They are rapidly permeable and occur on 0 to 8 percent slopes. They do not have layers within 5-1/2 feet of the surface that retard the downward movement of water. The coarse textured substratum of these soils is so permeable that shallow wells located close to septic tank disposal fields may be contaminated.

2 - <u>Moderate limitation</u>

These soil areas are generally satisfactory for septic tank disposal systems. The soils are rapidly permeable and have formed in sandy and gravelly materials, but they occur on 8 to 15 percent slopes. The location of septic tanks on slopes having gradients within this range requires careful site selection. Additional site preparation may also be necessary to insure satisfactory functioning of the disposal system. These soils are so permeable that shallow wells located close to, or downslope from, disposal fields may be contaminated. Some of the soils in this limitation class occur on 0 to 8 percent slopes, but they have a very rocky, very stony, or extremely stony surface and contain stones below the surface.

3 - Severe limitation

These soil areas require intensive site preparation to overcome soil conditions when used for septic tank disposal systems where house lots are about 1/2 acre in size. However, some of these soil areas may be satisfactory for septic tank sewage disposal for rural homes or low density residential areas where houses are far apart.

The soil problems involve one or more of the following conditions:

a. bedrock within about 5-1/2 feet of the surface,

b. slow or moderately slow permeability in the substratum,

c. a high water table, at or near the surface, for periods ranging in duration from 4 to 9 months or longer each year,

d. slope gradients greater than 15 percent,

e. subject to flooding by stream overflow, or

f. extremely rocky surface.

This limitation class is divided into six subclasses and a letter suffix is used to indicate the major limiting factor. Some soils have other limiting factors in addition to the major one that is designated.

The six subclasses are defined as follows:

3D - Severe limitation (hardpan-deep)

These areas consist of well drained and somewhat excessively drained soils that have a hardpan or silt or clay layer at a depth of 2-1/2 to 5-1/2 feet from the surface. The hardpan or silt or clay layer is slowly permeable and retards the downward movement of water.

3F - Severe limitation (flooding)

These areas consist of excessively drained through well drained alluvial soils subject to flooding by stream overflow.

3H - <u>Severe limitation (hardpan-shallow)</u>

These areas consist of well drained and somewhat excessively drained soils that have a hardpan or silt or clay layer within 2-1/2 feet of the surface. These layers are slowly permeable and retard the downward movement of water.

3R - <u>Severe limitation (bedrock)</u>

These soil areas have bedrock within 5-1/2 feet of the surface and contain many bedrock outcrops, but in many places the bedrock is within 2-1/2 feet of the surface. In addition, there are some areas deeper than 5-1/2 feet to bedrock that have many large boulders on and in the soil.

3S - <u>Severe limitation (slope)</u>

These areas consist of excessively drained through well drained soils that have a rapidly permeable substratum. The soils occupy areas having slope gradients greater than 15 percent. The installation of septic tanks on such steep areas is difficult and requires special site preparation. In addition, sewage effluent may seep to the surface downslope from the disposal system creating a nuisance and menacing public health. These permeable soils provide little filtering action and nearby shallow wells may become polluted.

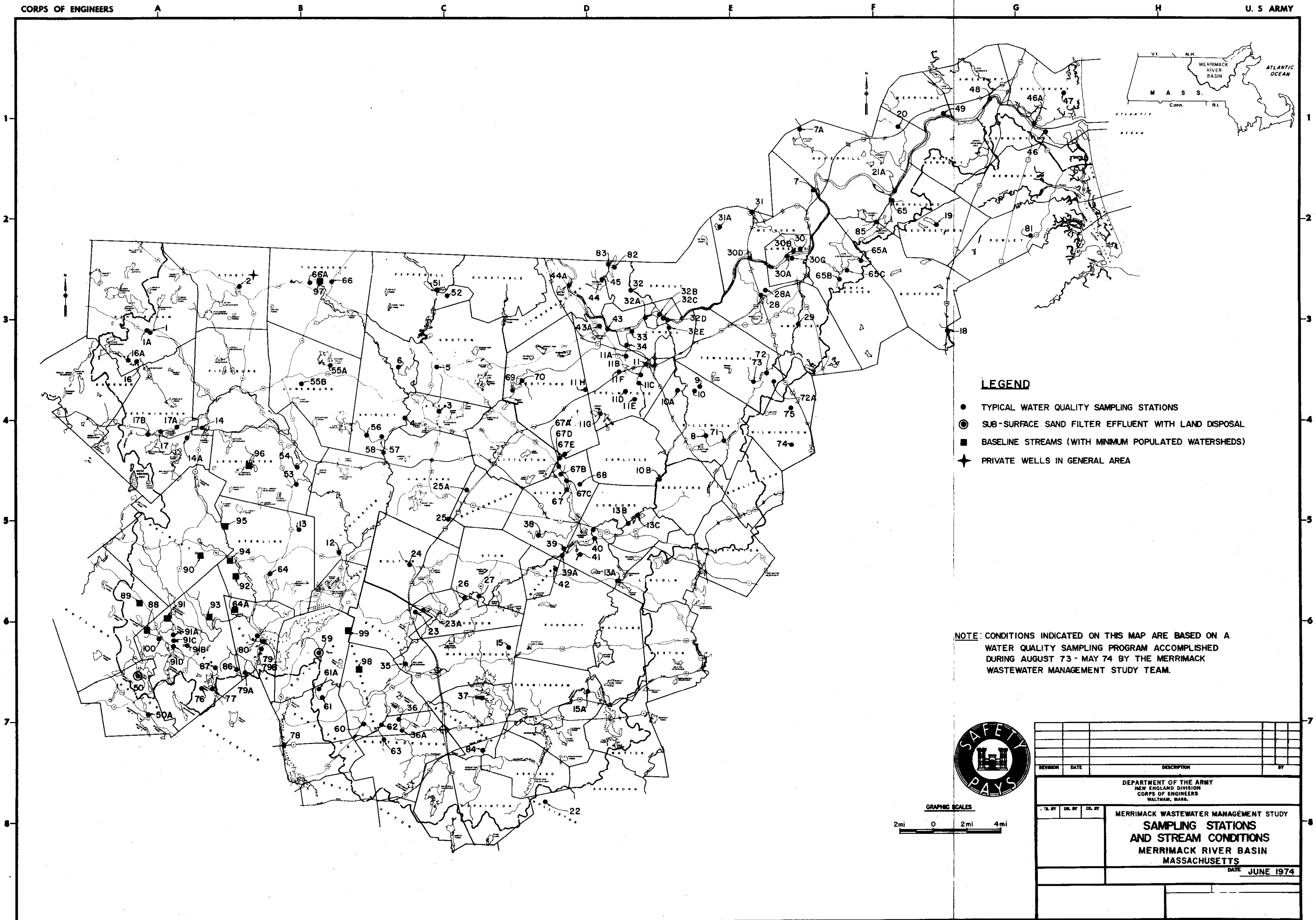
3W - <u>Severe limitation (wetness)</u>

These areas consist of moderately well drained, poorly drained, and very poorly drained soils. They are affected by a high water table that impedes or prevents the absorption of sewage effluent. Moderately well drained soils have excess seepage water or a water table that is about 1-1/2 to 2 feet below the surface in wet seasons. This condition commonly persists for 4 or 5 months of the year.

The poorly drained soils have a water table at or near the surface for 7 to 9 months of the year. The very poorly drained soils have a water table at or near the surface most of the year. Some of these soils also have a very stony or extremely stony surface and a slowly permeable hardpan within 2 feet of the surface.

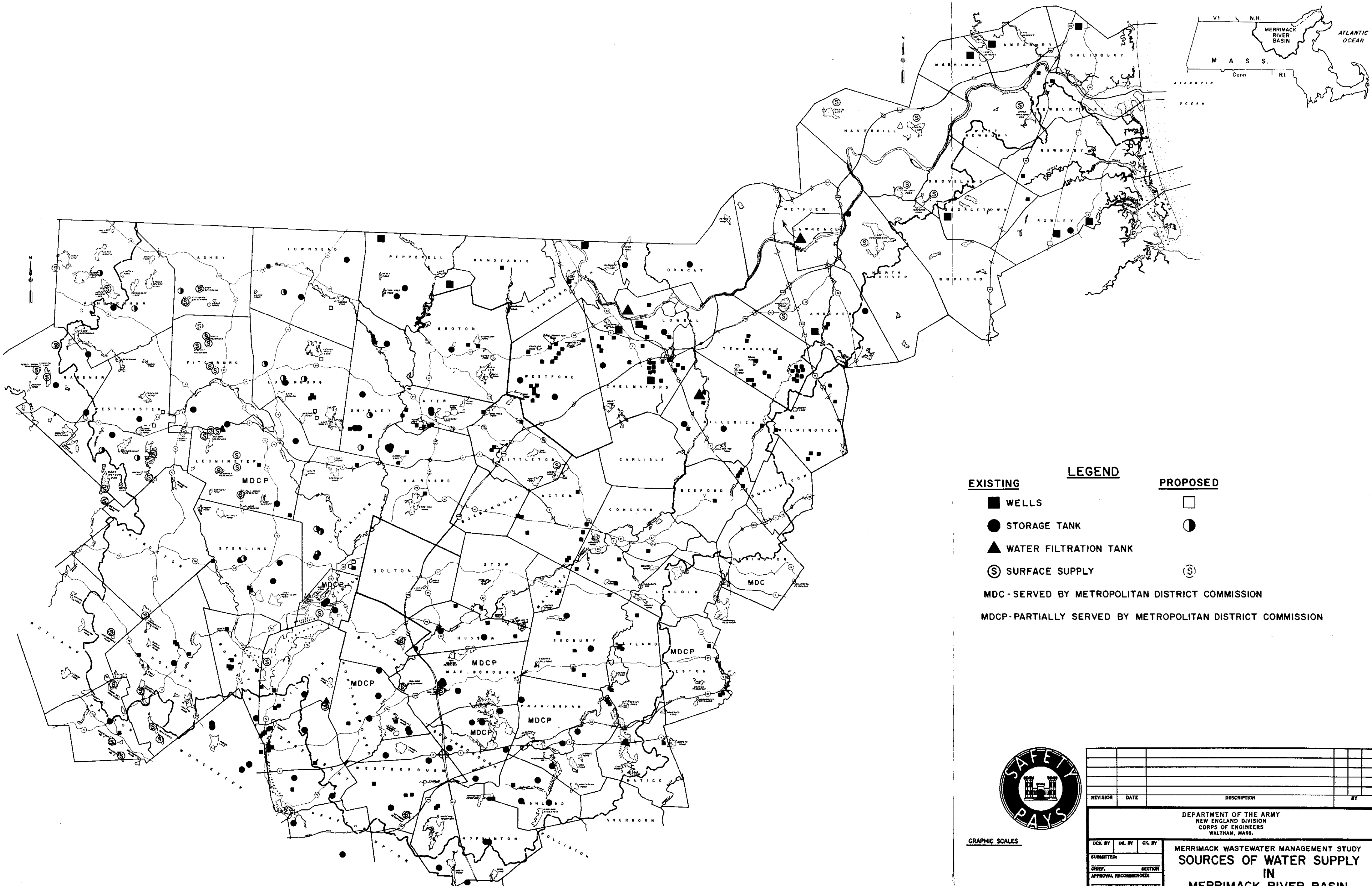
X - Unclassified

The soils in these areas have been removed, buried, or otherwise altered. The characteristics of individual areas are too variable for proper soil classification. Therefore, the areas are not rated and placed into one of the limitation classes. These areas require on-site determination.



CORPS OF ENGINEERS
U. S ARMY
LEGEND
TYPICAL WATER QUALITY SAMPLING STATIONS
SUB-SURFACE SAND FILTER EFFLUENT WITH LAND DISPOSAL
BASELINE STREAMS (WITH MINIMUM POPULATED WATERSHEDS)
PRIVATE WELLS IN GENERAL AREA
NOTE: CONDITIONS INDICATED ON THIS MAP ARE BASED ON A WATER QUALITY SAMPLING PROGRAM ACCOMPLISHED DURING AUGUST 73 - MAY 74 BY THE MERRIMACK WASTEWATER MANAGEMENT STUDY TEAM.
MERRIMACK RIVER BASIN
ATLANTIC OCEAN
SAFETY PAYS
GRAPHIC SCALES
2mi 0 2mi 4mi
REVISION
DATE
DESCRIPTION
BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
MERRIMACK WASTEWATER MANAGEMENT STUDY
SAMPLING STATIONS
AND STREAM CONDITIONS
MERRIMACK RIVER BASIN
MASSACHUSETTS
DATE JUNE 1974

CORPS OF ENGINEERS A B C D E F G H U. S ARMY



LEGEND

EXISTING		PROPOSED
■	WELLS	□
●	STORAGE TANK	◑
▲	WATER FILTRATION TANK	
Ⓢ	SURFACE SUPPLY	Ⓢ

MDC - SERVED BY METROPOLITAN DISTRICT COMMISSION

MDCP - PARTIALLY SERVED BY METROPOLITAN DISTRICT COMMISSION

SAFETY PAYS

GRAPHIC SCALES

REVISION	DATE	DESCRIPTION	BY

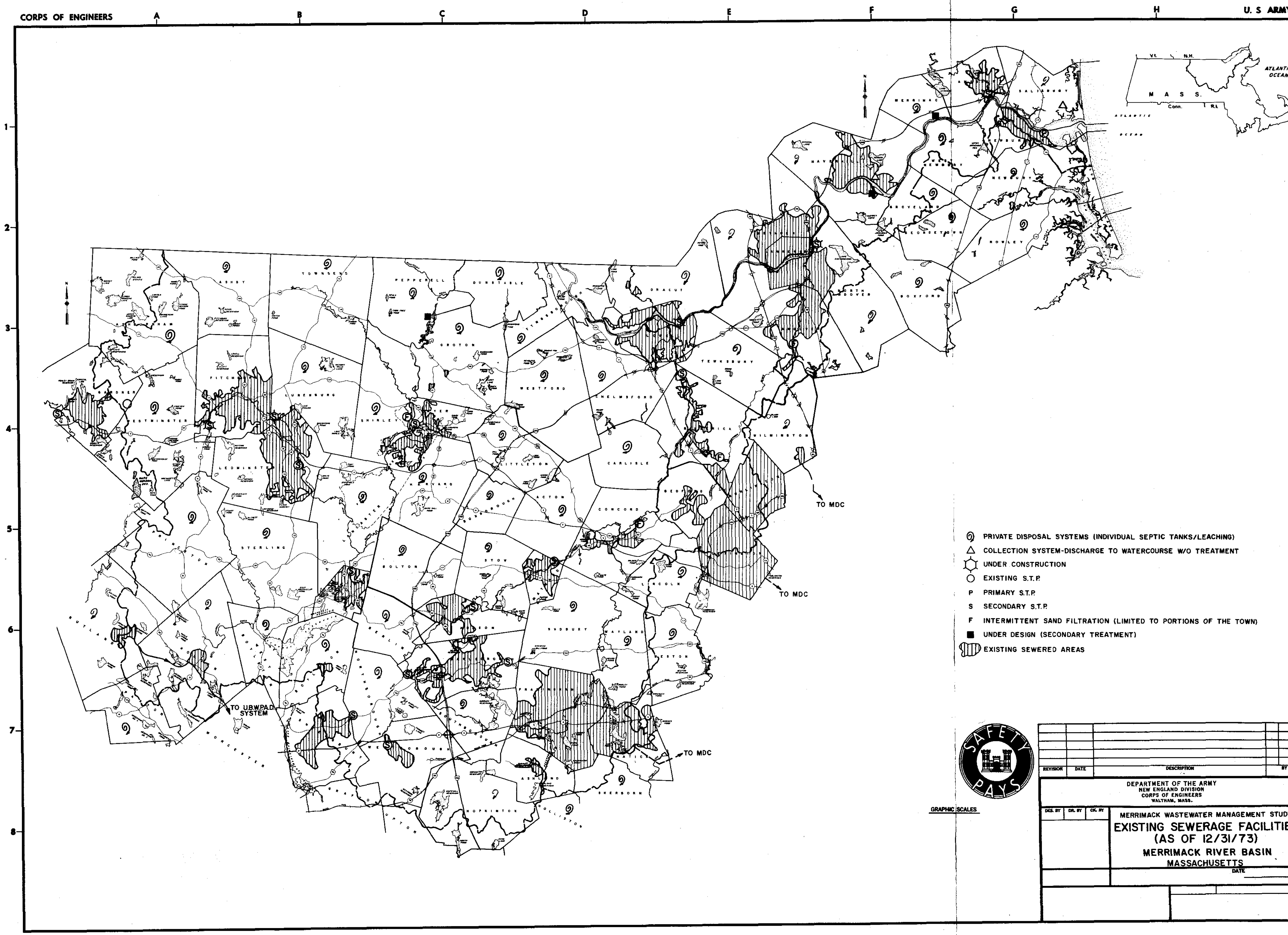
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

MERRIMACK WASTEWATER MANAGEMENT STUDY

SOURCES OF WATER SUPPLY IN MERRIMACK RIVER BASIN

MASSACHUSETTS

DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH
APPROVED DATE
CHIEF, ENGINEERING DIVISION
SCALE | SPEC. NO.
DRAWING NUMBER
SHEET


CORPS OF ENGINEERS
U. S ARMY
ATLANTIC OCEAN
MASS.
TO MDC
TO MDC
TO MDC
TO UBWPAD SYSTEM
ASHBY
TOWNSEND
PEPPERELL
DUNSTABLE
GROTON
WESTFORD
CHELMSFORD
TEWKSBURY
DRACUT
WILMINGTON
CARLISLE
LITTLETON
ACTON
CONCORD
STOW
BOLTON
STERLING
LINCOLN
SUDBURY
WAYLAND
HOPKINTON
SHERBORN
SALISBURY
ROWLEY
BOXFORD
PRIVATE DISPOSAL SYSTEMS (INDIVIDUAL SEPTIC TANKS/LEACHING)
COLLECTION SYSTEM-DISCHARGE TO WATERCOURSE W/O TREATMENT
UNDER CONSTRUCTION
EXISTING S.T.P.
P PRIMARY S.T.P.
S SECONDARY S.T.P.
F INTERMITTENT SAND FILTRATION (LIMITED TO PORTIONS OF THE TOWN)
UNDER DESIGN (SECONDARY TREATMENT)
EXISTING SEWERED AREAS
SAFETY PAYS
GRAPHIC SCALES
REVISION DATE DESCRIPTION BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
DES. BY DR. BY CK. BY
MERRIMACK WASTEWATER MANAGEMENT STUDY
EXISTING SEWERAGE FACILITIES
(AS OF 12/31/73)
MERRIMACK RIVER BASIN
MASSACHUSETTS
DATE